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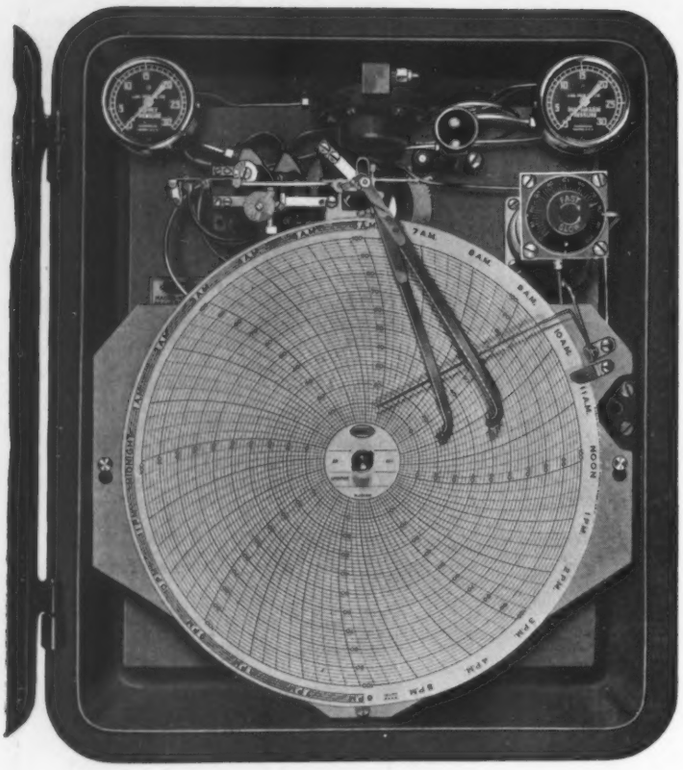

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VOLUME 20, NO. 3 MARCH, 1941

REFINER
AND NATURAL GASOLINE MANUFACTURER

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The Look Box

WHILE the petroleum industry is justly pointing out that there is no shortage of its products and none likely in relation to the defense program, it would be well to point to another record. There have been no strikes in the petroleum industry. Although Refiner and Natural Gasoline Manufacturer does not propose to speak for the thousands of men who work in the manufacturing division of the industry, it does venture to predict that there will be as little labor trouble in this industry as any other and it hopes there will be none.

To the Credit of Refinery Labor

The labor situation in petroleum is a credit to management and to labor. Management has done a good job of taking care of its working forces and the working forces are doing a good job of taking care of management, as well as the fuel and lubrication needs of the nation and its people.

Only recently a book appeared, the biography of a Communist, who at one time tried to organize seamen in a campaign to stifle ocean transportation. He admitted that he had such scant success with the crews of tankers that his progress was nothing. He simply gave up and admitted that tanker crews were so well treated that Communism had no attraction.

Decent treatment is no more than men deserve. What is heartening is proof that men appreciate decent treatment.

Above all that, however, is the impression that the men in refining and natural gasoline plants consider what they do of importance beyond their own petty desires. Somehow they seem to realize that gasoline and lubricants are two products the nation needs and they are determined that they shall be provided.

So far they are being provided on a basis that calls for no strikes and no threats of labor disturbance.

The industry has a lot to offer the whole industrial makeup of this country. Also the labor element in the industry has a lot that could be imitated by workmen in other industries.

Somehow wages continue upward, working hours grow fewer and output increases under whatever combination of mutual understanding prevails in petroleum.

WHEN politicians start on a revenue hunt the oil industry seems to be the only game in sight. The most recent instance is the move in the Texas legislature to impose a tax of one cent a gallon on all gasoline manufactured in the state.

An Axe for the Oily Goose

That this would bring high revenue is evident, until the proposal is analyzed. Revenue seekers assume that refining plants in Texas would continue to make as much gasoline under the tax imposition as they do with no such tax. If each gallon of Texas gasoline went across the state line with this one-cent penalty on it, the immediate result would be the reduction of refinery throughput in Texas and equal increase in throughput in states where no such tax exists.

In time much of the refining capacity of Texas would be abandoned while that of other states would be increased. As much as 90 percent of

the gasoline made in Texas goes outside the state for consumption.

Perhaps the proposal is so preposterous that the venture will fail of its own weight. But the petroleum industry is such an easy victim that it may collect a few more pieces of lead from the political gun.

Already it has been shown that oil pays close to half the tax total for Texas. It looks like the ideal of the politicians is to have oil carry the full tax load.

Good Fire Record

FOR ALL of the hazards that abound in refining and other activities that concern oil, the probability of fire is three times as high for the home as for the oil plant. This is one of the facts revealed in a sound picture, which has been prepared by The Atlantic Refining Company. As J. Howard Myers, director of safety and fire prevention of the company puts it:

"The film reveals that the probability of a tank fire in the average petroleum plant is one fire per plant in 450 years. The corresponding probability for the average residence is one fire in every 150 years. The splendid record of the petroleum industry in preventing fire is a tribute to the efforts of employes through the production, transportation, refining, distributing and marketing fields."

To the Contrary Notwithstanding

FROM road tests, laboratory experiments and a manufacturing venture that has failed, it would seem that a case has been proven against the feasibility of alcohol as motor fuel. The mixture as proposed is not as good fuel as gasoline. The effort to make it economically was a failure. Furthermore there is no need for augmenting the motor-fuel supply. Even the petroleum industry admits there is too much gasoline available.

Still, as part of the United States Department of Agriculture, a laboratory has been set up, with one of its objectives the production of motor fuel on a commercial basis. In announcing the venture Dr. Henry G. Knight, chief of the Bureau of Agricultural Chemistry and Engineering said:

"The work on motor fuels offers important possibilities for greatly increasing industrial utilization of farm products, including corn. Division charged with this work will investigate alcohol and other products from fermented materials, which may be considered of possible use as fuels in internal combustion engines.

"Investigation also will deal with the development of liquid fuels, other than those produced by fermentation, and solids producible from farm crops as well as gaseous fuels derivable from crop residues such as cobs, hulls, straw and stalks."

The laboratory has been built at Peoria, Illinois. Sylvester T. Schicktanz is head of the motor-fuel-research work. It is planned to have 200 chemists at work on the venture. A pilot plant will be built for determining the feasibility of commercial production of alky-gas.

Too Much and Too Easy

PERHAPS it would have been better for the petroleum industry had it been compelled to provide its own market. Use of these products has come with so little industry effort that the growing volume may have been too little appreciated. Appreciation increases with effort of accomplishment, and the industry has given little effort to providing its market.

For 35 years, the consumption of gasoline has grown with hardly a sag in the upward curve. Recently, the furnace distillate market has shot upward and the industry has not provided all of this market. In 1939, asphalt sales were 8 percent higher than in 1938.

Other industries are charmed by such an expanding market. Since the petroleum industry frequently uses this expanding market for selling merchandise at a loss, it too may be only charmed by what has been provided from outside sources.

This is all mere speculation, since continued growth seems likely and with scant effort on the part of the industry. But to dig for a market might compel men to make merchandise accordingly.

Deliver the Goods Or Go Broke

AS AN attitude of industry and one phase of free enterprise, here is a significant paragraph by J. Howard Pew, president of Sun Oil Company, before the forty-fifth annual Congress of American Industry:

"We have never assumed a divine right to a share and a place in our industry. If some one else could serve the public better in quality and price, he was entitled to the business. That is still our attitude. It is the attitude of the whole industry. Every one recognizes that his right to continue in business depends upon his ability to give the public what it wants at prices which it is both willing and able to pay."

His subject was "Preserving the Private Enterprise System," and the paragraph suggests this definition—deliver the goods or go broke.

Treating of Furnace Oils Presents Difficult Problem

A. W. TRUSTY

FURNACE oil can no longer be considered a by-product of the refining industry. The new seasonal demand for fuel oil is tending to balance the former summer seasonal demand for gasoline, thus permitting the refiner to maintain his crude runs at a higher throughput throughout the winter.

The following table indicates that the market for burner oil is mainly in the Eastern States:[1]

	1936 Oil Burner Sales, Percent
Pacific Coast	4.1
Middle West	14.2
Middle and South Atlantic	30.0
Metropolitan New York	31.5
New England	20.2

The furnace oil market has future possibilities almost as great as the gasoline market. Although the installation of an oil burner is now considered a luxury, especially in localities where cheap coal is available, the fact that 60 percent of the oil heater sales in 1936 were made to buyers with annual incomes between $1800 and $4500, indicates that soon this commodity will be considered as much a necessity as is the automobile.

The rapid introduction of the range or blue-flame burner has increased the sales of kerosene or range oil. The Number 1 fuel oil in the East has been changed to a kerosene specification to insure a suitable oil for these range burners.

A comparison of the types of burners offered on the market in 1936 and 1940 is shown:

1936 Percent	1936 No.	1936 Grade Fuel Oil Recommended	1940 Percent	1940 No.	1940 Grade Fuel Oil Recommended
10.2	118	1	10.8	147	1
10.1	116	2	6.8	92	2
65.7	757	3	71.0	961	3
1.1	13	4	0.2	5	4
4.3	50	5	8.5	116	5
8.6	99	6	2.7	37	6
100.0	1153	....	100.0	1358	....

It is noted that the majority of the models are designed for a No. 3 grade of oil.

Note: In the tabulation shown above, the type of oil recommended is listed as the lighter grade where a range of several grades are recommended.

The types of burners in service in 1936[2] were:

	Percent
Vaporizing	1.4
Vertical Rotary	9.3
Horizontal Rotary	1.0
Pressure	88.3

Generally clean, distilled oils are necessary for satisfactory operation of pressure burners. A viscosity of 45 seconds is considered the maximum for good operation on pressure-type burners operating at low feed rates.

Pot type and vaporizing burners having no fans or blowers generally burn a No. 1 grade of oil. Domestic atomizing type burners of the gun and vertical rotary type generally burn a No. 3 oil.

Significance of Tests

Flash Point—The flash point originally was employed to indicate the hazards of storage. In addition there is a rough relationship between flash point and ease of ignition in burners, particularly those that involve a partial vaporization of the oil in starting.

Pour Point—The pour point is an indication of the point at which an oil becomes too viscous to move freely. Also it indicates the point at which solid hydrocarbons might separate out and plug lines and strainers. Oils should be chosen with pour points lower than the prevailing storage temperature, especially where gravity feed is used.

Water and Sediment—Any appreciable amount of foreign matter, such as insoluble carbonaceous matter,

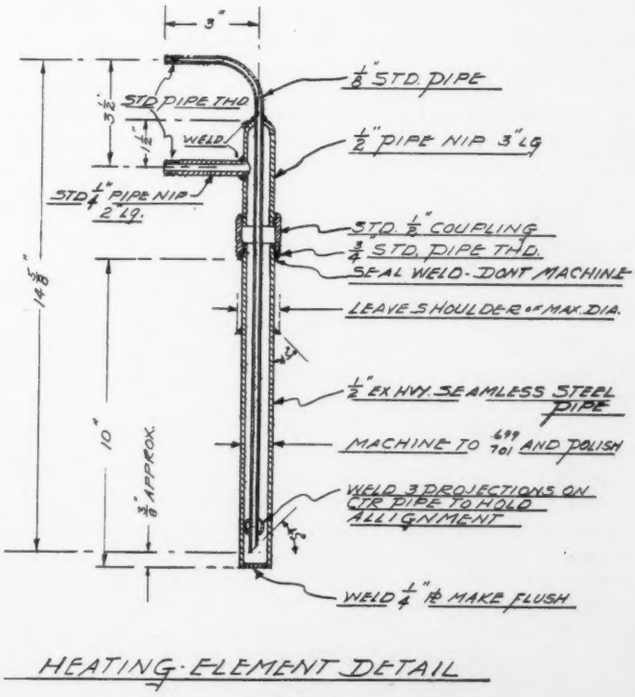


Figure 1

rust, sand or scale will clog strainers, lines and burner tips.

Carbon Residue—The carbon residue test originally was designed to indicate the carbon-forming tendency of an oil when used in an internal combustion engine. The correlation between the carbon residue test and the quality of furnace oils is not definitely established at present unless used in connection with other of the quality tests.

Ash—The determination of ash is a measure of the amount of non-combustible material present. It will include tank scale and dirt picked up from lines and tankage. The total ash does not indicate the presence of those salts that will cause corrosion by hydrolysis or that will cause fluxing action on refractories.

Distillation—The distillation test is probably the most important test to determine the adaptability of fuels for various types of burners. The temperature at which 10 percent is distilled is a rough index of the ease of ignition. The 90 percent distilled temperature in relation to the end point gives some indication of possible difficulty from coke formation.

Sulfur—The sulfur content is not considered of importance in furnace oils, since, in general the sulfur content of oils is much lower than the coal that would otherwise be used.

Color—Color has little significance in the quality of furnace oils except to indicate the uniformity of the material.

Thermal Value—The thermal value of the oil is important. The following table shows the approximate thermal values of fuel oils:

GRADE	Approximate Gravity	B.t.u. per Gallon
1	38–40	136,000
2	34–36	138,500
3	28–32	141,000
4	24–26	145,000
5	18–22	148,500
6	14–16	152,000

It is noted that oils of heaviest gravity have the smallest heat value per pound, but have enough more pounds per gallon that a 10° A.P.I. oil with 3 percent less heat per pound than a 20° A.P.I. oil will have 3.5 percent more heat per gallon.

Stability—At the present time there is no uniform or standard method of testing furnace oils to predict the sludge forming tendency. Such a method, similar to the gum stability test on gasoline, no doubt will later be developed. Three methods of testing for stability are listed.

1. Ferric Sulphate Test—A 1 percent solution of ferric sulphate is agitated with two volumes of the oil being tested. The shaken oil is examined after the oil and water layer has separated. A heavy precipitate, or scum, indicates the presence of iron soap, and condemns the oil as a suitable furnace oil. The absence of a layer of scum or precipitate in the interface, indicates that the oil would be satisfactory.

2. A Heater Test[4]—A 14-inch length of .7-inch I.D. pipe is fitted with a ⅛-inch steam pipe, as shown in Figure 1. The oil bath is surrounded by a water bath which is held at a temperature of 60-80° F. One quart of oil is placed in the bath, the heater immersed to a depth of 8½ inches, and the steam admitted. At the end of 24 or 96 hours, the heater is removed, the deposit scraped and washed with benzol into a beaker. The insoluble material is filtered through a tared Gooch crucible, the crucible heated in an oven at a temperature not over 200° F., cooled and weighed.

This heater test originally was developed for residual fuel oils, but has been found applicable to distillate fuel oils.

3. The Oven Test—100 c.c. of the furnace oil is placed in a 150 c.c. Pyrex beaker, a copper corrosion strip added, and the beaker placed in an oven at 212° F. for 24 hours. At the end of the heating period, the beaker is allowed to cool for 30 minutes. The oil is filtered through a tared Gooch crucible or tared filter paper, and washed with precipitation naphtha. The paper or crucible is dried in an oven at 212° F., cooled and weighed. The weight of insoluble material is an indication of the sludge- or resin-depositing tendency of the oil.

Cause of Sludge Deposition

The deposition of sludge during the heating test apparently is caused by condensation of some of the more unstable unsaturated hydrocarbons. However, it should be noted that the unsaturates are not the sole cause of the sludge. In some cases, it is reported that straight-run oils have caused complaints from sludge deposition. Part of the deposit in this case was no doubt caused by the formation of soaps by reaction of the copper or iron equipment with organic acids in the oil.

Resinous condensation products of carbazole (or its derivatives) with olefins have been described by Michel.[5] For example, propylene condenses with carbazole to give a soft resin, which boils at 410° F. to 464° F. at 1 m.m. pressure. Cyclohexene and carbazole yield a hard resin which distils at 518° F. to 644° F. at 1 m.m. pressure. In most cracked oils there are sufficient phenols and organic acids present to combine with the unsaturates to form high-boiling and insoluble resins. The condensation increases rapidly with an increase in temperature and also with the presence of catalysts such as copper.

The source of most furnace oils is usually:

(1) Straight-run oil from the topping operation.

(2) Gas oil from the cracking operation.

In the past, most of the furnace oils were straight-run products. Cracked furnace oils could be produced which would meet all the specifications for a No. 1, 2 or 3 oil, but complaints of poor color stability and sludge formation were received in some cases.

Color stability is a requisite for a satisfactory oil, not from a performance viewpoint, but from the customer sales viewpoint.

Another more serious complaint was the deposition of a sludge, or resin, which clogged filters, lines and burner tips. The factors which accelerated this condition were:

(1) Brass or copper lines and screens. The copper metal acted as a catalyst to accelerate the deposition.

(2) Heat. Some types of burners were equipped with pumps which by-passed the excess oil back into the storage tanks. This excess oil received a certain amount of preheating, which gradually raises the temperature of the main body of oil in the storage tank.

(3) The type of oil. In general, the more highly cracked oils, containing high percentage of unsaturated compounds, gave more trouble with sludge deposition.

To avoid complaints of this nature, the refiner chose to sell a straight-run product, which usually was color stable and gave satisfactory operation from the burner performance viewpoint. However, as the demand for furnace oils increased, the refiner found it more and more desirable to include cracked gas oils in his products. In most cases it has been found that some kind of chemical treatment is necessary to produce a satisfactory furnace oil from the cracked gas oils.

A strong caustic wash has been found effective in

TABLE 1

Fuel Oil Specifications: A.S.T.M. D396-39T, Detailed Requirements of Fuel Oils[a]

GRADE[b]	End Point, °F.		Pour Point °F.	Water & B. S. %	Carbon Residue, %	Ash %	Distillation Temperatures Degrees F.				Viscosity, Seconds			
							10% Point	90% Point		End Point	Saybolt Universal @ 100 °F.		Saybolt Furol @ 122 °F.	
	Min.	Max.	Max.	Max.	Max.	Max.	Max.	Max.	Min.	Max.	Max.	Min.	Max.	Min.
No. 1 Fuel Oil: A distillate oil for use in burners requiring a volatile fuel	100 or legal	165	0.[e]	Trace	0.05[d] on 10% Residuum		410			560[e]				
No. 2 Fuel Oil: A distillate oil for use in burners requiring a moderately volatile fuel	110 or legal	190	10[e]	0.05	.25[f] on 10% Residuum		440	600						
No. 3 Fuel Oil: A distillate oil for use in burners requiring a low viscosity fuel	110 or legal	230	20[e]	0.10	.15 Straight			675	600[g]		45			
No. 5 Fuel Oil: An oil for use in burners requiring a medium viscosity fuel	130 or legal			1.00		.10						50	40	
No. 6 Fuel Oil: An oil for use in burners equipped with preheaters permitting a high viscosity fuel	150			2.00[h]									300	45

[a] Recognizing the necessity for low-sulphur fuel oils used in connection with heat-treatment, non-ferrous metal, glass and ceramic furnaces and other special uses, a sulphur requirement may be specified in accordance with the following table:

Grade of Fuel Oil	Sulphur, Maximum, Percent
No. 1	0.5
No. 2	0.5
No. 3	0.75
No. 5	No Limit
No 6	No Limit

Other sulphur limits may be specified only by mutual agreement between the purchaser and seller.

[b] It is the intent of these classifications that failure to meet any requirement of a given grade does not automatically place an oil in the next lower grade unless in fact it meets all requirements of the lower grade.

[e] Lower or higher pour points may be specified whenever required by conditions of storage or use. However, these specifications shall not require a pour point lower than 0° F. under any conditions.

[d] The carbon residue on 10 percent residuum may be increased to a maximum of 0.12 percent when this oil is to be used in other than sleeve-type blue-flame burners. This limit may be specified by mutual agreement between the purchaser and the seller.

[e] The maximum end point may be increased to 590° F. when this oil is to be used in other than sleeve-type blue-flame burner.

[f] To meet certain burner requirements, the carbon-residue limit on this oil may be reduced to 0.15 percent on 10 percent residuum.

[g] This requirement may be waived if the A. P. I. Gravity is 26 or lower.

[h] The amount of water by distillation plus the sediment by extraction shall not exceed 2.00 percent. The amount of sediment by extraction shall not exceed 0.50 percent. A deduction in quantity shall be made for all water and sediment in excess of 1.00 percent.

treating cracked furnace oils. Usually a caustic wash is not sufficient treatment to produce a satisfactory oil as tested by any of the three suggested methods, but, in most cases, the caustic wash will reduce the sludge depositing tendency to half of its original value.

Treatment with sulfuric acid and subsequent neutralization with an alkali is probably the surest and most effective method of producing a satisfactory oil. The quantity of acid will vary with the nature of the oil, but 3 to 10 pounds of acid per barrel will be sufficient for most types of cracked gas oil.

The neutralization and subsequent brightening of the treated oil usually gives the treater some difficulty with eliminating the emulsions. The use of a destabilizer has been found effective in accelerating the brightening operation, especially when used in connection with a steam coil for heating the oil and an air coil for light blowing.

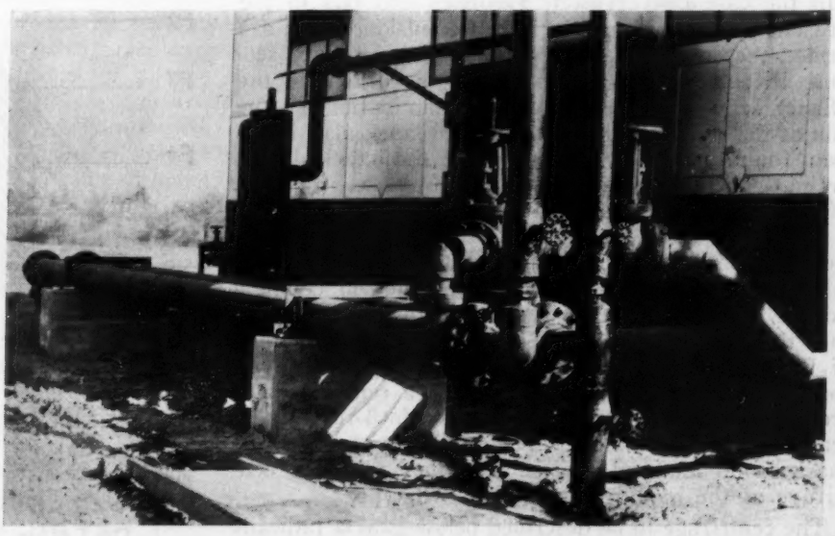
References

[1] Batchelder, Refiner. Nov. 1936.
[2] Fuel Oil J. 15 (7) 31, 1937.
[3] Dr. C. W. Rippie, Solvay Sales Co.
[4] Batchelder, Refiner. November, 1936. P. 485.
[5] Michel, U. S. Patent, 1,916,629, July 4, 1933.

CONTROL of gasoline temperature within narrow limits greatly speeds up the treatment of gasoline for the removal of sulphur, there being a minimum temperature below which treatment must be greatly prolonged to reach required quality.

At Talco Asphalt & Refining Company, Mt. Pleasant, Texas, a heat exchanger has been set up outside the treating building, through which the incoming stream of gasoline may be circulated, while live steam may be admitted around the pipes, and the temperature of the gasoline held as desired.

Use of the heat exchanger during cool weather enables the stream of gasoline to be treated as rapidly as during summer months, and thus prevents "bottlenecking" or slowing down of production through the inability of a given step to maintain the pace of others.



Centrifugal Separation of Doctor-Blackstrap Emulsions

HAROLD BOTTOMLEY,
Chief Chemist, Cosden Petroleum Corporation

IN ALL doctor-treating systems blackstrap emulsions, i.e. PbS—spent Plumbite—oil, are present to some extent depending on the type of material being treated and the local conditions affecting such treatment. It is the general condition that more blackstrap emulsion is formed in doctor treating sour gasolines than those of lesser mercaptan content. Also, the type of treating equipment, batch or continuous, affects the emulsion formation in addition to other factors such as the turbulence obtaining in the mixture of the reagents with the oil, the hardness of the water used in making up the doctor solution and soaps present in the oil being treated.

The continual formation of these emulsions which are difficult to break economically by former means substantiates many of the arguments against doctor treatment. The loss of the oil contained in the emulsion, the chemical inactivity of the lead sulfide that is coated with the oil and the utilities required to properly regenerate the recovered blackstrap are items that loom large in the treating schedule. If the oil phase is not completely removed from the treating solution heavy ends remain that upon subsequent revivification of the lead sulfide are oxidized, thus causing deterioration and increase in the gum content of stocks treated with this solution. In addition to the monetary loss involved by evaporating the gasoline from the blackstrap the vapors evolved constitute a distinct fire hazard.

Gravity Settling Not Sufficient

In the case of very sour gasolines and oils in the kerosene-distillate range blackstrap emulsions often are formed that cannot be separated by mere gravity settling. In some plants this blackstrap is drawn to the refinery waste system to avoid contamination of the bulk of the treating solution. In some plants, also, it has been found necessary to segregate the cracked and straight-run doctor solutions chiefly because of the oil left in the recovered doctor. It is evident, therefore, that if essentially all of the oil phase can be removed from the emulsion the solutions resulting therefrom are basically the same and can be held together in common storage. It can be seen from years of operating experience that gravity settling is not a satisfactory method of handling these emulsions. If the force of gravity could be increased several fold as in a centrifuge the problem would be greatly diminished. Until recently no centrifuge was available that could continuously discharge solid material. Berger describes a special centrifuge of the modified Laughlin bowl type.

The centrifuge to be described below is of a radically different design in that the solid material is discharged continuously from the bowl without the use of any moving mechanical contrivance. The nozzle bowl type centrifuge continuously discharges three streams and in order that its operation can be readily understood reference is made to Figures 1 and 2.

Centrifuge Operating Details

The feed, consisting of an emulsion of spent doctor solution, lead sulfide and oil, enters at the top of the distributor F1 and after passing through the inlet passages flows upward between the intermediate discs F4. These discs have distribution holes placed in vertical rows and are visible on the left hand side of the cut. The light liquid component, in this case oil, flows toward the center of the bowl and upward through the neck of the top disc F9 and from there out into the upper bowl cover to be conducted through an outlet spout to storage.

The heavier components consisting of concentrated lead sulfide slurry and spent doctor flow toward the periphery of the bowl. The lead sulfide together with a certain quantity of spent doctor flows through the nozzles F5 into the lower bowl cover while the balance of the spent doctor, substantially lead sulfide free, flows through channels on the upper side of the top disc through the neck of the bowl hood F3 into the center bowl cover. The hood neck of the bowl is fitted

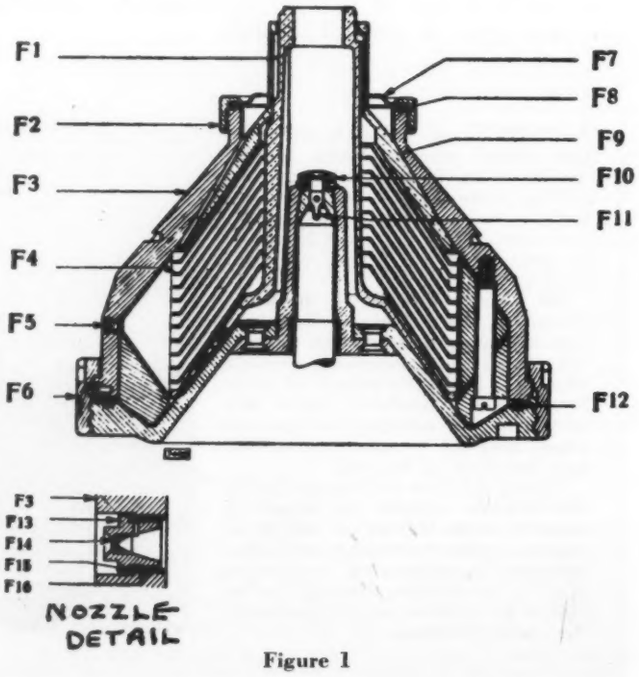


Figure 1

with an interchangeable gravity disc F7 which is kept in position by the gravity lock ring F2 and regulates the separation of the various components.

The centrifuge and accessory equipment as installed at the Cosden Petroleum Corporation's Big Spring, Texas, refinery is shown in the diagrammatic flow sheet, Figure 3.

During the period under review blackstrap emulsions resulting from the doctor treatment of straight-run and cracked gasolines and distillates were stored in the cone-bottom vessel at the left of the sketch. Means is provided for circulating this material to insure uniformity of the feed to the centrifuge. After leaving the open impeller-type centrifugal charge pump the emulsion passes through a small baffled settling tank where sand and any other foreign matter heavier than the feed drops out. To insure continuous operation several screens were installed in the feed line between the settler and the centrifuge. At the inlet to the machine are two other lines tied into the feed line for the purpose of injecting caustic, reclaimed doctor solution or water into the centrifuge. This addition is necessary only when the emulsion is so heavy that a sufficient quantity of spent doctor is not present to carry the lead sulfide through the bowl nozzles. Also, at times, when a preponderance of gasoline is present in the emulsion sufficient carrier must be added in the form of doctor solution or water to carry the lead sulfide out of the gasoline phase. By proper operation and attention to the fundamentals of centrifugal separation a gasoline of any desired clarity may be discharged from the upper collecting bowl cover of the centrifuge.

The intermediate discharge consists of clean spent doctor solution and may be mixed with the discharge from the nozzles, this mixture then being taken directly to the regenerators. By maintaining a moderately sized stream from the intermediate discharge ring the lead sulfide and oil phases are kept from coming in contact after once entering the bowl. It has been found that the lead sulfide derived from the centrifuged blackstrap emulsion is much more easily oxidized than that previously obtained by steaming and blowing. In fact, it is likely that considerable revivification takes place in the centrifuge itself due to the intimate contact between the air present in the machine and the lead sulfide-caustic mixture.

Variable Throughput

The capacity of the machine is variable between certain limits depending upon the size of nozzles used in the bowl and the tenacity of the blackstrap emulsion being processed. Under adverse conditions of a very tight emulsion and .0625-inch diameter nozzles a throughput of 25 barrels per hour is easily attained. With a normal emulsion and .10-inch diameter nozzles 40-45 barrels per hour of raw charge is capable of being processed through the machine.

During three years of continuous operation no operating difficulties have presented themselves other than the routine care and attention usually accorded to any high speed rotating equipment. A 15-horsepower explosion-proof motor is used to drive the machine, the power being transmitted by multiple V belts. The bowl of the centrifuge operates at 5400 to 5600 r.p.m. and should a load in excess of the machine's capacity be placed upon it a centrifugal clutch in the drive allows slippage to take place until the overload is corrected.

In a novel installation of this type where a considerable investment is required for the equipment the question arises as to its economic value and the length of time required to amortize the capital outlay. With the present installation its worth is very apparent and a quick pay out was obtained. Below appear the economics of the set-up with the approximate pay-out time indicated.

In the case under discussion the blackstrap derived from treating 1000 barrels of gasoline amounts to about 20 barrels and contains approximately 50 percent gasoline, 25 percent spent doctor solution and 25 percent by volume of solid lead sulfide. The gasoline is practically 100 percent recoverable and thus amount to 10 barrels per thousand barrels of gasoline treated in the doctor plant. Therefore the saving in gasoline due to centrifugal operation is 420 gallons per 1000 barrels gasoline treated, or at 3 cents per gallon is worth $12.60. If 6000 barrels of gasoline is treated per day the recovered gasoline has a value of $75.60 per day. A great saving in steam is also effected in not having to heat the emulsion for gravity settling.

To process the above mentioned amount of blackstrap it would be necessary to operate the centrifuge six hours

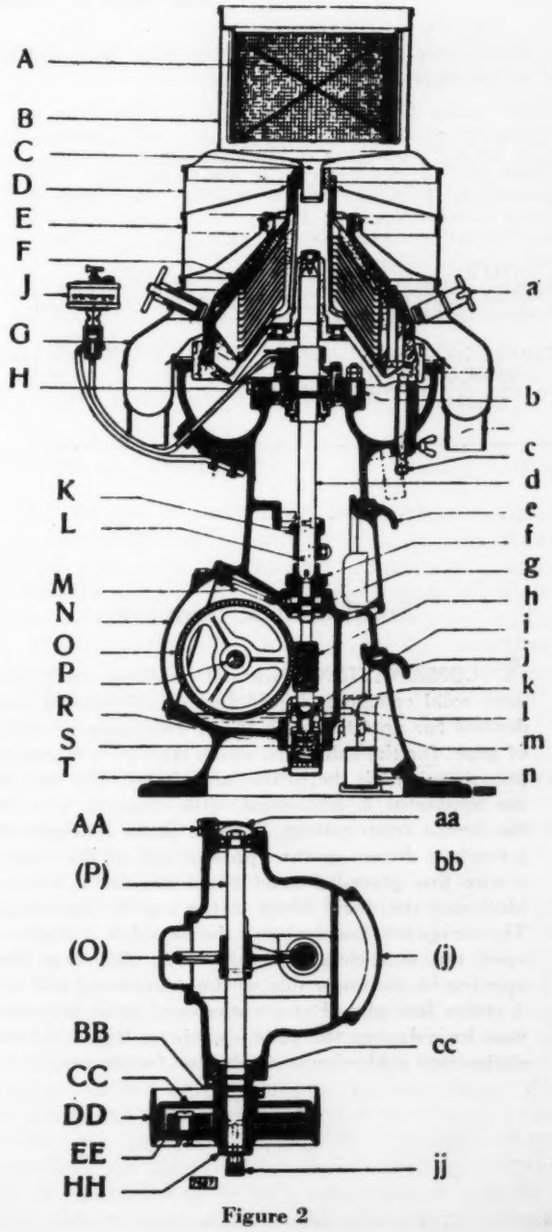


Figure 2

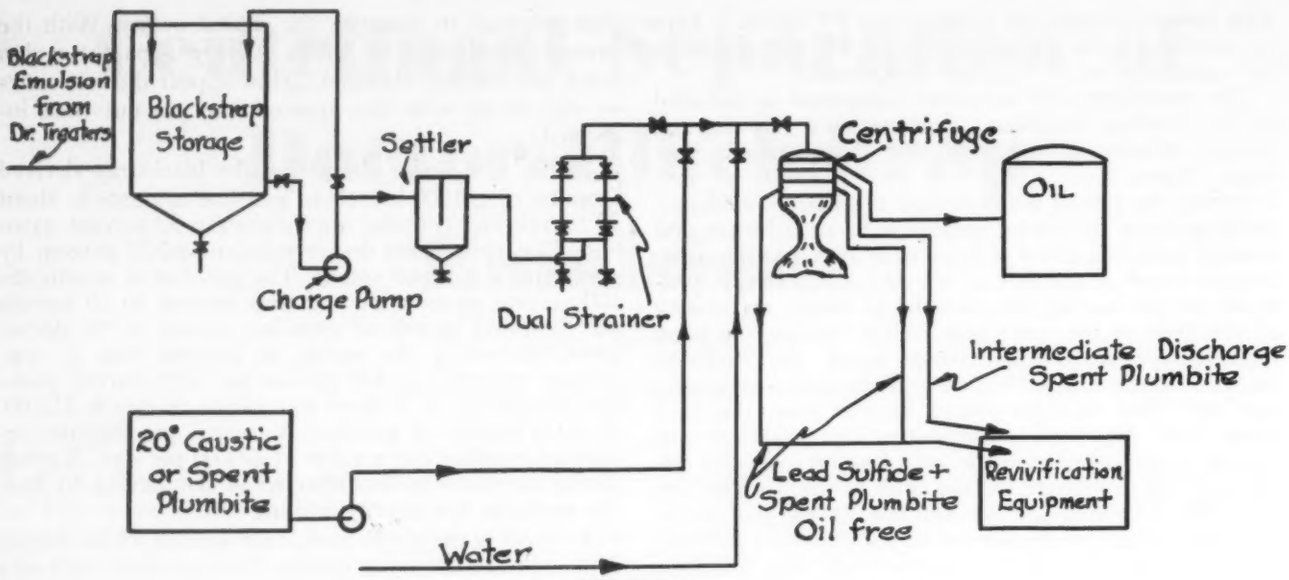


FIGURE 3
Flow Sheet of Centrifuge and Accessory Equipment

per day. Since the regular treater may be used there will be no operating labor charge.

Electric power (70.8 KWH@1 cent)....70.8 cents per day
Maintenance .....21.5 cents per day
(One set belts per year at $7.20 per set)
(Four sets nozzles per year at $16.11 per set)
Depreciation at 5% per year on $5000....83.3 cents per day
Interest on investment at 3%.....50.0 cents per day
Total Operating Costs, 300-day year.....$2.256 per day

PAY OUT:
Savings in gasoline recovered.....$75.60 per day
Deduct operating costs..... 2.256 per day

Pay out income.....$73.344 per day

Or: $\frac{\$5000.00}{73.344}$ is equal to 68.15 days payout.

The above recapitulation does not take into account the savings in steam and air used in the subsequent revivification of the doctor solution but it goes without saying that it will be a sizeable amount.

The operation as described in this article will probably not obtain in every refinery but may in many. Many refiners do not realize the loss they are getting from the gasoline volatilized from their doctor-blackstrap emulsions. Doctor treating may be made more economical and practical than ever before by utilizing centrifugal separation for the complete recovery of gasoline, kerosene and distillates from the emulsions formed in the treating process.

Solid Caustic Reducer

A COMBINATION ramp and steaming vat to reduce solid caustic to liquid for use in treating was devised for an Oklahoma plant. The ramp is made of pipe, for the side rails, which start on a concrete pier upon which the drums are placed. The top of the apparatus is horizontal, with stops to prevent the drums from rolling. When a drum is required, a truck is driven on the opposite end of the ramp, a wire line placed around the drum for a rolling hitch and the drum lifted to the top for steaming. The receptacle for draining the liquid is a shallow, open top semi-circular steel vessel, placed so the opening in the lower side of the drum head will fit. A steam line placed at a convenient point provides ease in reducing the solid caustic to liquid, which drains into a blow case nearby for future use.

Perco Copper Sweetening

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THE term sweetening, though for many years used synonymously with doctor treating, has in recent years come to be used in a much broader sense. With the advent of other processes for sweetening sour petroleum hydrocarbons, the refiner is provided with some alternatives when contemplating building a new or revamping an old treating system. Since doctor sweetening is the oldest and probably the most widely used gasoline treating process, the present discussion will be confined to the merits of Perco Copper Sweetening as compared to doctor sweetening.

During the early days of the petroleum refining industry, the margin of profit to the refiner usually was such that it was not necessary to hold motor fuel production costs to an absolute minimum, and the refiner was content to accept doctor treating as fulfilling his requirements in the production of a doctor-sweet and non-corrosive product. However, the specifications and marketing conditions governing the manufacture and sale of present-day automotive and aviation fuels are such that the doctor-sweetening process no longer may be accepted and justified so casually. Petroleum technologists have done a commendable job in improving the doctor process, but by no means has it been improved to the extent that the many inherent disadvantages have been overcome.

With the advent of high-octane specifications for motor fuels and the widespread use of gum inhibitors, doctor sweetening began to be regarded as a rather expensive treating process not only because of generally high operating costs but also because of the serious deterioration of the product being sweetened. In recent years considerable emphasis has been placed on the development of other processes for sweetening petroleum oils. Inasmuch as the odorous constituents of light-oil distillates; i.e. mercaptans, were chemical reducing agents, numerous oxidizing agents were tried and compounds of copper appeared on the scene as a likely substitute for the plumbite system. Due to the fact that the element copper possessed two stages of oxidation and was capable of being readily reduced to the cuprous state, and likewise re-oxidized to the cupric state, it offered attractive possibilities in the sweetening of sour hydrocarbon oils.

Chemistry of Copper Sweetening

The application of copper sweetening, represented by the Perco processes, makes full use of the two stages of oxidation of copper. Stated in another way, copper sweetening is simply an oxidation-reduction reaction involving the mercaptan constituents of the sour oil and cupric copper solutions. In the study of various copper solutions, it was found that these solutions containing relatively high concentrations of chloride or bromide ions[1] reacted in the following manner exemplified by cupric chloride:

1. $4\,RSH + 4\,CuCl_2 \rightarrow 2\,RSSR + 4\,CuCl + 4\,HCl$
   (Mercaptan; Cupric Chloride; Disulphide; Cuprous Chloride; Hydrochloric Acid)

The cuprous chloride formed in accordance with this equation is readily converted back to cupric chloride by oxidation with air in accordance with the equation 2:

2. $4\,CuCl + 4\,HCl + O_2 \rightarrow 4\,CuCl_2 + 2\,H_2O$
   (Cuprous Chloride; Hydrochloric Acid; Oxygen (Air); Cupric Chloride; Water)

By adding equation 1 and 2, the simple expression in equation 3 is obtained, which summarizes the net result of the copper sweetening reaction:

3. $4\,RSH + O_2 \rightarrow 2\,RSSR + 2\,H_2O$
   (Mercaptan; Oxygen; Disulfide; Water)

The nature of the foregoing reactions imposes upon the design and operation of a copper sweetening unit two very fundamental conditions; namely, (a) that the sour oil be intimately contacted with the copper solution, and (b) that the cuprous chloride and hydrochloric acid formed in the reaction in equation I be retained in the solution and intimately contacted with molecular oxygen as the revivifying agent. As a result of these two requirements, two separate and distinct modes of application of copper sweetening have been developed which are generally known as the "solid process" and the "liquid or solution process," both of which are based upon identical chemical principles.

It is essential in either process to have the sour oil free of hydrogen sulfide and elementary sulfur prior to contact with the copper reagent. Unless these substances are removed by stabilization or refractionation, caustic washing usually is employed in the conventional manner for the removal of hydrogen sulfide or a caustic solution of polysulfide ions[2] may be employed for the removal of both elementary or corrosive sulfur and hydrogen sulfide. Some gasolines have an inherent tendency to retain caustic solution in suspension for periods longer than is economical to allow for proper settling. In these cases, it is expedient to add some sort of a filter between the caustic settler and the copper treater;

usually sand and rock to knock out the final traces of suspended caustic.

Modes of Application

Solid Process of Copper Sweetening: In the Perco "Solid Process" of copper sweetening a nominal excess of air is injected into the sour-gasoline stream under such conditions of pressure as to effect solution of the air in the gasoline, which is then passed over a filter bed of copper reagent comprising an

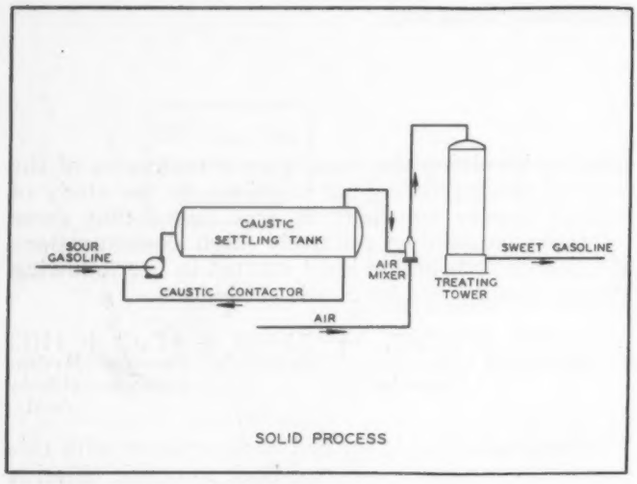


Figure 1

adsorbent carrier impregnated with a cupric chloride solution. This method is characterized by the fact that the conversion of the mercaptans to disulfides and the re-conversion of the cuprous copper to cupric copper takes place simultaneously and, of course, in the same reaction zone. This method of copper sweetening is applicable when the injection of the oxygen of the air and protracted contact of the gasoline with the solid reagent do not result in any deleterious effects on the color, gum and general stability of the product. From the reaction zone or reagent tower, the gasoline, doctor-sweet and non-corrosive, passes to finished storage without further treatment.

This process is illustrated by the flow diagram given in Figure 1. In many plants where caustic washing is not required, it is possible to utilize the stabilizer or up-stream pressure to charge the oil to the unit through a pressure-reducing valve. In those cases where caustic or polysulfide washing is required, it is expedient to adjust the caustic settler or sand filter discharge to such a pressure to permit the solution of the required amount of air in the sour-gasoline stream prior to contact with the sweetening reagent. Usually there is only a very nominal pressure drop through the reagent tower, probably of the order of two to five pounds. By making use of an automatic air-gasoline flow controller or proportioning valve and the regulation of the back pressure on the treating tower, such plants require no more than casual attention during operation.

There is one significant feature, however, that must be observed in the operation of solid-process units and that is the moisture content of the reagent. Normally, the percentage of water in the reagent should be about 15 percent and care should be taken to prevent water from entering the system through the gasoline- or air-supply lines. In those cases where the mercaptan content of the gasoline is relatively high, considerable water of reaction is formed. This may cause the moisture content of the reagent to gradually build up until it is necessary for the reagent to be removed from the tower and dried to the proper moisture content. On the contrary, there are many gasoline streams that are so dehydrated in the process of distillation that the tendency is for the gasoline in passing over the reagent bed to carry with it not only the water of reacion but also some of the original water of solution of the copper reagent. In the early stages of such an operation it is necessary to establish the ratio of water lost from the reagent bed to the quantity of gasoline treated in order to compensate for this loss by periodically adding water to the reagent bed. Some plants that require the addition of water to the reagent bed have been in operation for nearly five years without having to replace or revivify the reagent, and there are many other plants in operation that bid fair to equal or better this record of operation.

In those installations where there is an accumulation of water in the reagent bed it is necessary for it to be removed from the tower and dehydrated or dried. Operating cycles of 6 to 12 months in such instances are not uncommon. When the moisture content of the reagent is up to about 35 percent there is usually an increase in pressure drop through the reagent tower. At this point the stream of gasoline may be cut into the spare tower without interrupting the treating schedule.

Solution Process of Copper Sweetening: This type of operation is characterized by the fact that (a) an aqueous solution of cupric chloride is employed without the use of adsorbent carrier materials, (b) the sweetening and regenerating operations are conducted in separate zones to eliminate the addition of air (oxygen) to the gasoline stream, and (c) the use of sodium sulfide after-wash for the stabilization of

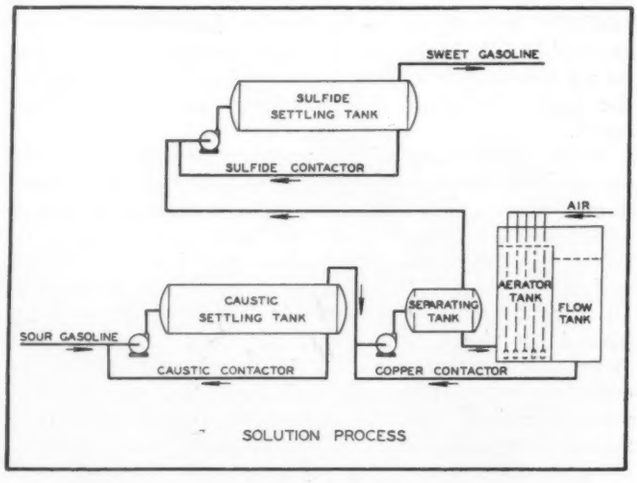
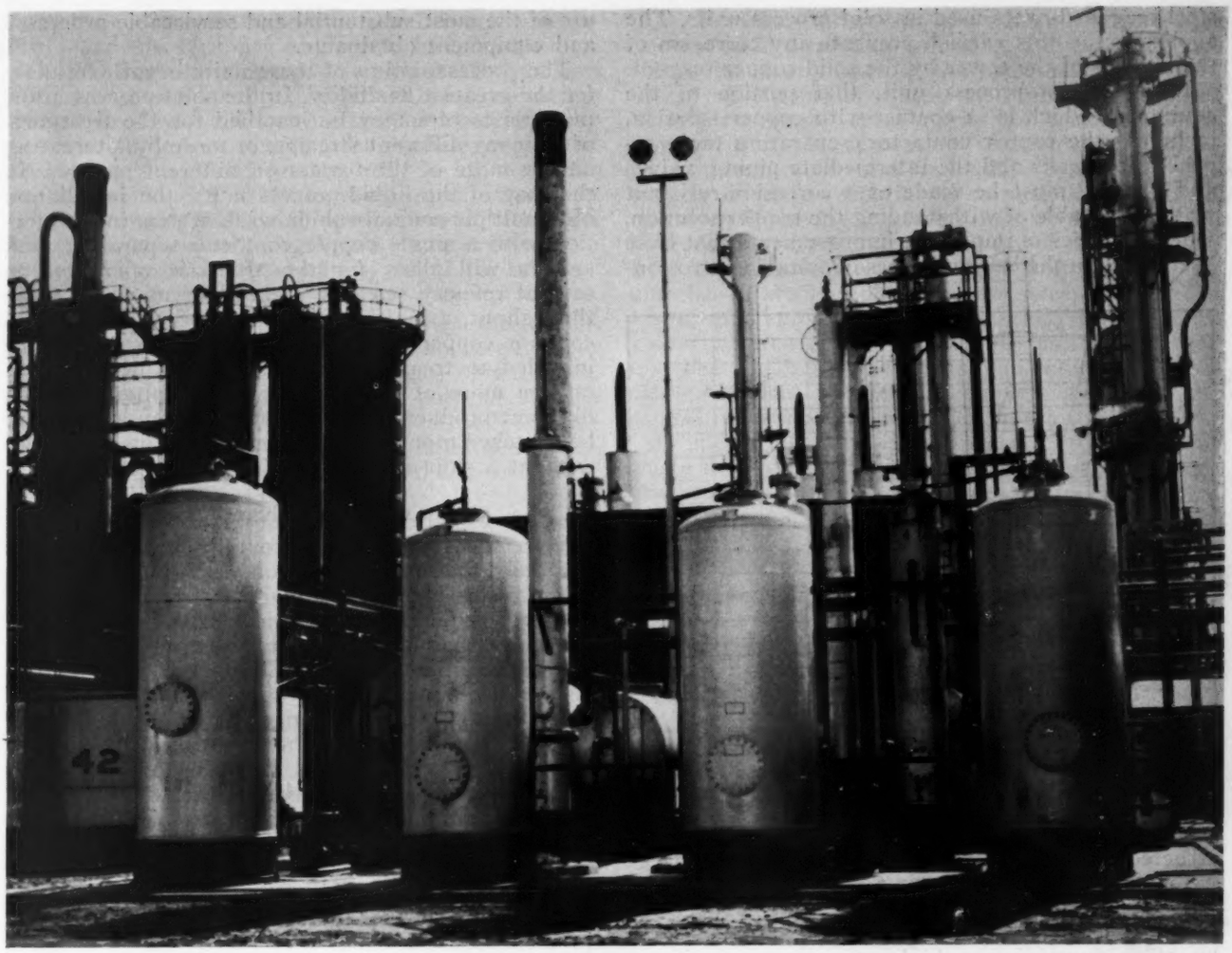


Figure 2

the sweetened product. This modification of copper sweetening is exemplified in the flow diagram given in Figure 2. It is to be noted that the sour gasoline from the caustic pre-wash system is charged directly and continuously to one suction line of the copper contactor pump, while copper solution, in about equal volumes, enters the other suction line of the copper contactor. From the copper contactor the gasoline-copper solution mixture passes to the horizontal separating tank wherein complete separation of the two



Twelve hundred barrels per day Perco Solid Copper treating unit. This unit comprises, reading from left to right, a sand fitler and three treating towers for parallel treating operations.

liquid phases takes place immediately. The copper solution, of course, gravitates to the bottom and under the pressure of the separating tank is discharged continuously to the aerator tank. In the aerator tank the copper solution under atmospheric pressure is blown with air at about 10 pounds pressure through a series of alundum diffuser tubes located in the bottom thereof to effect complete regeneration of the solution in accordance with Equation 2, above.

The gasoline from the separating tank passes to one suction line of the sulfide contactor wherein it is continuously washed with an alkaline solution of sodium sulfide[3]. The sodium sulfide-wash is the final step in the solution process of copper sweetening and is designed to remove any traces of copper that may remain in the gasoline stream leaving the separator tank. From the sulfide settling tank, the gasoline is sweet and non-corrosive and ready for blending to finished motor fuels.

The items of control required of the solution process units are (a) ratio of copper solution to gasoline in the copper contactor; (b) control of the liquid level in the separator tank; (c) ratio of sulfide solution to gasoline in the sulfide contactor; (d) maintenance of the oxidation potential[4]; (e) the so-called dye test for copper in the finished gasoline[5]; and (f) periodic analyses of the copper and sulfide solutions. The oxidation potential is usually determined once each 24 hours and, of course, is controlled by the amount of air to the regeneration system. The concentrations of the copper and sodium sulfide solutions do not undergo any sudden changes and, therefore, do not give rise to any emergencies. These solutions usually are analyzed once each week, according to an established routine and it is recommended that the copper solution be adjusted to normal strength by the addition of the required components; i.e., copper sulfate, sodium chloride and water, once each 30 or 60 days if necessary.

The dye test for the absence or presence of copper in the finished gasoline is the criterion for judging the efficiency of the sodium sulfide after-wash. In many refineries it is possible to make use of the spent caustic solutions used for hydrogen sulfide removal for the sodium sulfide solution and generally there is a surplus of this material from the caustic-wash system. In such cases, the expense of purchasing sulfide chemicals is eliminated.

Materials of Construction

The materials of construction for the pre-caustic wash and the sodium sulfide systems are ordinary steel, as required in any conventional caustic-washing system. It is customary to apply one or two coats of an acid-resisting varnish to the interior walls of the

steel reagent towers used in solid process units. The application of this varnish prevents any corrosion of the interior of the tower by the solid-copper reagent.

In a solution-process unit, that portion of the equipment which is in contact with copper solution, including the copper contactor, separating tank, regeneration tanks and the intermediate piping, valves and fittings, must be made of a corrosion-resistant material capable of withstanding the copper solution. Due to a series of important improvements that have been made in the last few years in suitable corrosion-resistant materials, the design of the recently constructed solution-process units differs to a very large extent from that of the first commercial unit put into operation several years ago. The copper contactor is a motor-driven centrifugal pump made of an alloy containing a high percentage of silicon. The separator tank is a glass-lined steel cylindrical vessel designed to withstand a working pressure of 50 pounds gauge. The regeneration and auxiliary tanks are of concrete construction in one rectangular piece with three partitions to give four separate compartments, two for series regeneration, one for the copper-solution over-flow from the second regeneration compartment and one for a stand-by which is used for mixing chemicals. The copper-solution lines may be of rubber-lined steel, while the copper-solution-gasoline lines and all connections are generally a laminated, canvas base bakelite. The valves may be either alloy or a glass-lined steel diaphragm type. Such a unit comprises a substantial construction from the standpoint of materials used. Much time and effort have been expended to simplify the design and construction and to give a compact, readily accessible unit.

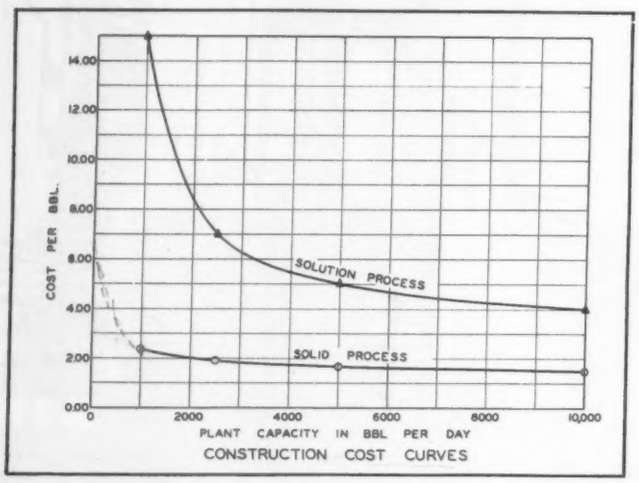


Figure 3

Estimated Construction Cost

The construction cost of these units will, of course, vary from one plant to another, depending upon the cost of materials, freight differentials and the amount of salvage equipment that is available. However, construction cost of the copper-sweetening units as given in the curves, Figure 3, are in keeping with other types of refinery and natural-gasoline equipment of equal serviceability. Whereas it was once the practice to more or less neglect the treating plant, it is necessary in this period of more rigid specifications and reduced margins of profit to make use of the most substantial and serviceable processes and equipment obtainable.

The process design of these units is such to allow for the greatest flexibility. In the solid process units, multiple towers may be installed for the treatment of as many different streams, or more by alternating one or more of the towers on different streams. In the case of the liquid-process units, the installation of a multiple-sodium-sulfide-wash system in conjunction with a single copper contactor-separating tank system will allow for the alternate operation on several refinery streams. Depending upon the daily throughput, a multiple solution process unit with a common copper solution regenerating system may be installed to treat as many streams as desired with one or more of the units operating alternately on different products. In either type system a unit may be switched momentarily from one stream to another without a shut-down.

Operating Advantages

Since the sweetening of sour hydrocarbon stocks is purely a chemical reaction, the consumption of chemicals is a matter of importance and operating economy requires that chemical costs be held to an absolute minimum. Theoretically from the summation of Equations 1 and 2 (Equation 3) there should be no consumption of the copper reagent in units of this type. In actual practice, however, this is not possible but results available are conclusive that chemical costs have been reduced to a relatively insignificant figure. The greatest variation in chemical consumption is in the solid-process units, depending upon whether or not it is necessary to dehydrate the reagent bed. In those instances where no dehydration of the reagent is required, operating cycles as long as five years have been obtained resulting in chemical costs as low as 0.01 cent per barrel. For those units in which it is necessary to remove the reagent from the tower for dehydration, chemical costs of the order of 0.1 cent per barrel are not uncommon. The consumption of copper reagent in the solution process units is much more uniform, and whatever chemical make-up is required is occasioned by mechanical losses as the carry-over of copper in the gasoline stream is negligible.

Operating labor costs may be reduced substantially, depending upon local conditions, without impairing the efficiency of the treating-plant operation. Due to the simplicity and practically automatic control of these units, the treating-plant operation may in some instances be combined with other refinery duties and the operating labor costs prorated accordingly. One operator per shift can attend to a four- to six-stream unit capable of processing as much as 25,000 barrels per day. For smaller units the shift operator, in addition to the treating plant, may assume other refinery duties such as stock transfer or attending stills.

It is recognized generally in the industry that copper sweetening lends a much improved quality to the treated products. This is due primarily to the nature of the chemical reaction in the sweetening step with copper solution which eliminates the formation of deleterious alkyl polysulfides[6] in the treated products. It has been shown that there is little or no difference in the effect of mercaptans and disulfides on anti-knock characteristics of hydrocarbon oils, whether with or without added tetraethyl lead. Thus, the copper-sweetening reaction should

have little effect on the octane number or the tetraethyl-lead susceptibility of a motor fuel. In commercial operations the copper-sweetening method consistently has shown no appreciable loss in octane rating, as compared with the loss suffered in doctor-treating systems. In some cases the clear octane number of the copper sweetened product may be of the order of 0.3 lower than that of the sour untreated product but with one or two cubic centimeters of tetraethyl lead the loss is usually regained by an increased lead susceptibility. The net result is, therefore, substantially no octane depreciation in the Perco processes.

These higher alkyl polysulfides which are formed in doctor sweetening, are analogous to peroxides in their effects on the various properties of gasolines. It has been pointed out that the polysulfides unquestionably have pro-knock characteristics[6], and the analogy may now be extended to other properties of gasoline such as potential gum and color stability. The elimination of these deleterious alkyl polysulfides, by the use of the copper-sweetening process, greatly improves the quality of the gasoline. In some instances, replacement of a doctor-sweetening unit by a Perco unit has resulted in a reduction of inhibitor requirements by as much as 50 percent, while color stability has been improved and corrosion tests have been reduced to a mere formality.

In the Perco processes, no suspended solids are present in the treating solutions, and no solids are formed as precipitates in the sweetening reactions. These conditions have resulted in the reduction of volumetric losses to a negligible quantity. It is obvious that the separation of immiscible liquids in the presence of solid lead sulfide which is necessary in doctor sweetening is a much more difficult operation involving a greater loss of sweetened oil than the corresponding separation of sweetened oil from copper solution. A thorough study of the volume losses attributable to doctor sweetening has in many cases emphasized the magnitude of this factor. In fact, Perco copper sweetening units have been installed which produced savings in volumetric losses alone sufficient to effect a complete payout of the capital investment in about 18 months.

In many localities the disposal of treating-plant waste is a problem. With copper-sweetening plants this problem is greatly minimized and in many cases may be eliminated.

Commercial Operations

The many advantages and economic success of the copper-sweetening processes herein described are evidenced by the fact that they are in use by 65 refiners and natural-gasoline manufacturers with

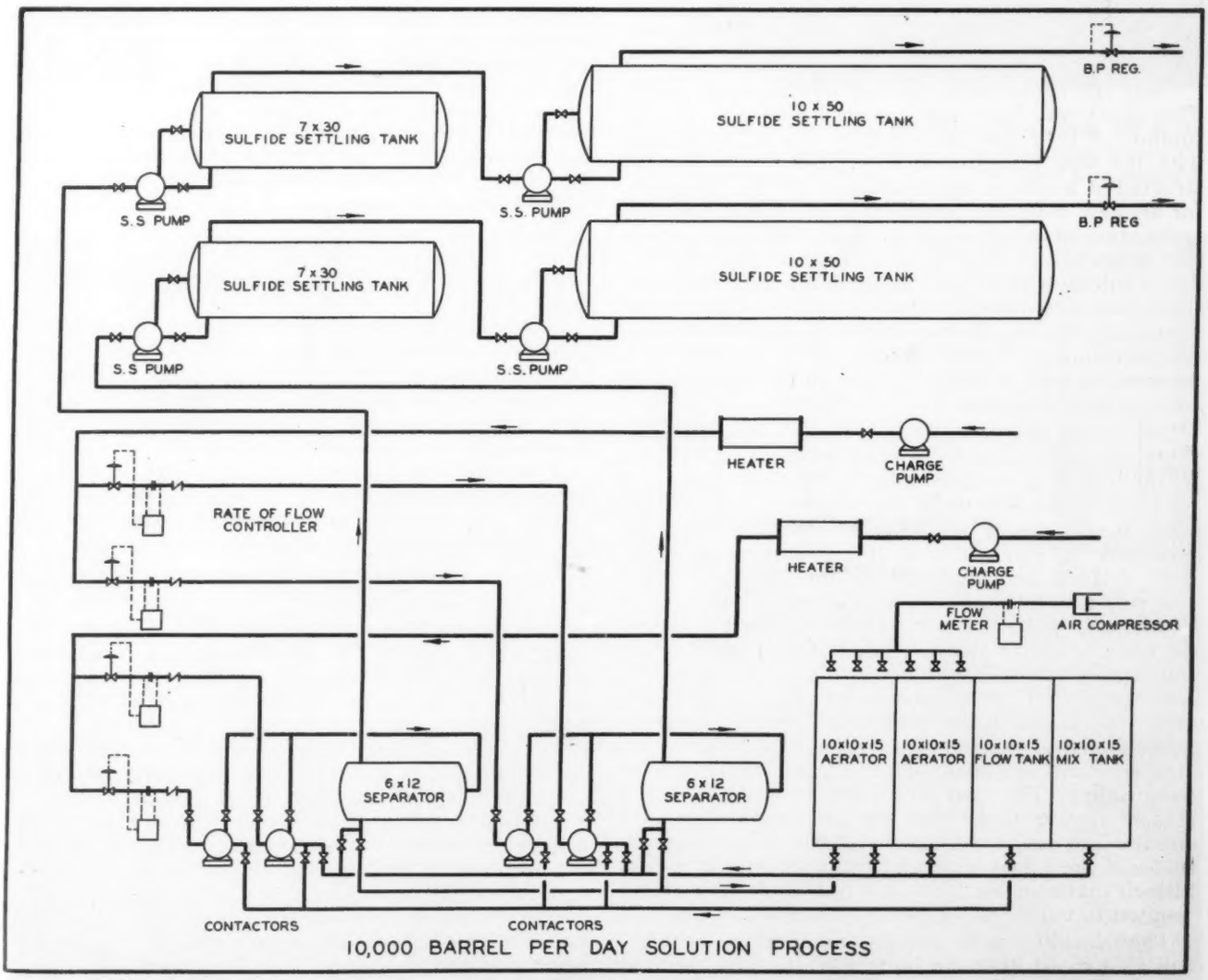


Figure 4

units installed and under construction in more than 125 separate plants.

To illustrate the many advantages of these copper-sweetening processes as described, reference is made to some commercial plants varying in duration of operation, as well as nominal daily capacities. For lack of time and space, it will not be possible to give a complete treatise on each of these plants; therefore, the remarks that follow will be confined to the more salient features of each.

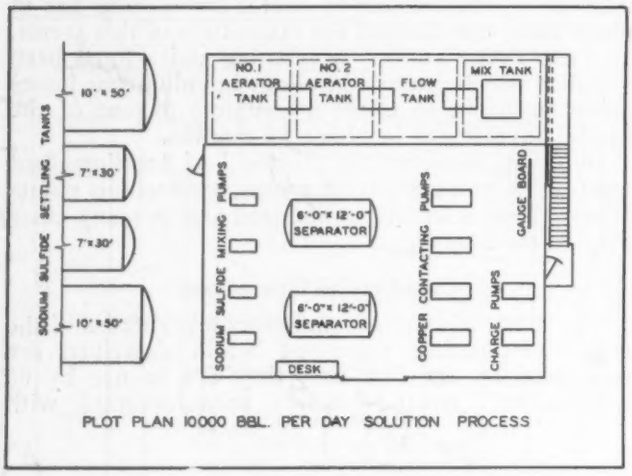


Figure 5

Plant A—10,000-barrel-per-day liquid-process Unit: This plant was built and put into operation in the summer of 1940. The construction was in accordance with the flow plan shown in Figure 4. It was constructed at a cost of approximately $35,000 complete for all new materials, except for the sulfide-settling tanks, two of which were in place, while the other two were moved from another part of the refinery. From the flow plan, it is to be noted that this unit comprises a two-stream system with a common regenerating system. This unit deserves more detailed consideration as it embodies the most recent design features, as well as the most substantial materials of construction available.

One of the most outstanding innovations that distinguishes this plant from older plants of this type is the concrete copper solution regeneration and auxiliary tanks instead of the wood-stave tanks formerly used. As may be noted from the flow diagram, this tank is essentially a 10 x 40-foot rectangular shell, divided into four sections by three partitions. The roof is solid, reinforced concrete, except for the aerator tube holes, the openings above each weir and the opening above the mix box in the mix tank. All openings in the tank roof are bordered with a 2-inch curb to prevent contamination by drainage into the tank. The aerator tube holders are precast concrete located vertically under the aerator tube holes in the tank roof and are anchored to the gunite tank floor by grouting. The two weirs between the first and second aerator tanks and the second aerator tank and the flow tank are located two feet below the tank roof and are 2 feet wide and made from a section of 24-inch diameter vitrified clay tile. Both weirs were grouted in before the gunite was applied.

The concrete tank outlets, numbering only six and all located near the bottom of the tank, consist of threaded bakelite nozzles inserted in galvanized sleeves in the tank wall and made up with bakelite jam nuts on soft rubber gaskets inside the tank and asbestos service sheet ring gaskets on the exterior of the tank. This construction as described makes for a much more substantial treating plant and offers a multiplicity of advantages over the wood-stave tank; namely, (a) elimination of some corrosion resistant tank outlets, (b) elimination of any fire hazard inherent in wood tanks, (c) reduction of copper solution chemical consumption to that occasioned by copper pump packing gland loss, if any, and sampling loss, and (d) construction cost no more and probably a little less than that for wood tanks of equivalent capacity. Right in this connection, it may be noted that one side wall of the concrete tank serves as the back wall of the treater house. Located in the treater house are the charge pumps, four copper contactors, two separator tanks, four sulfide pumps, instrument panel and operator's desk, as shown in the plot plan in Figure 5.

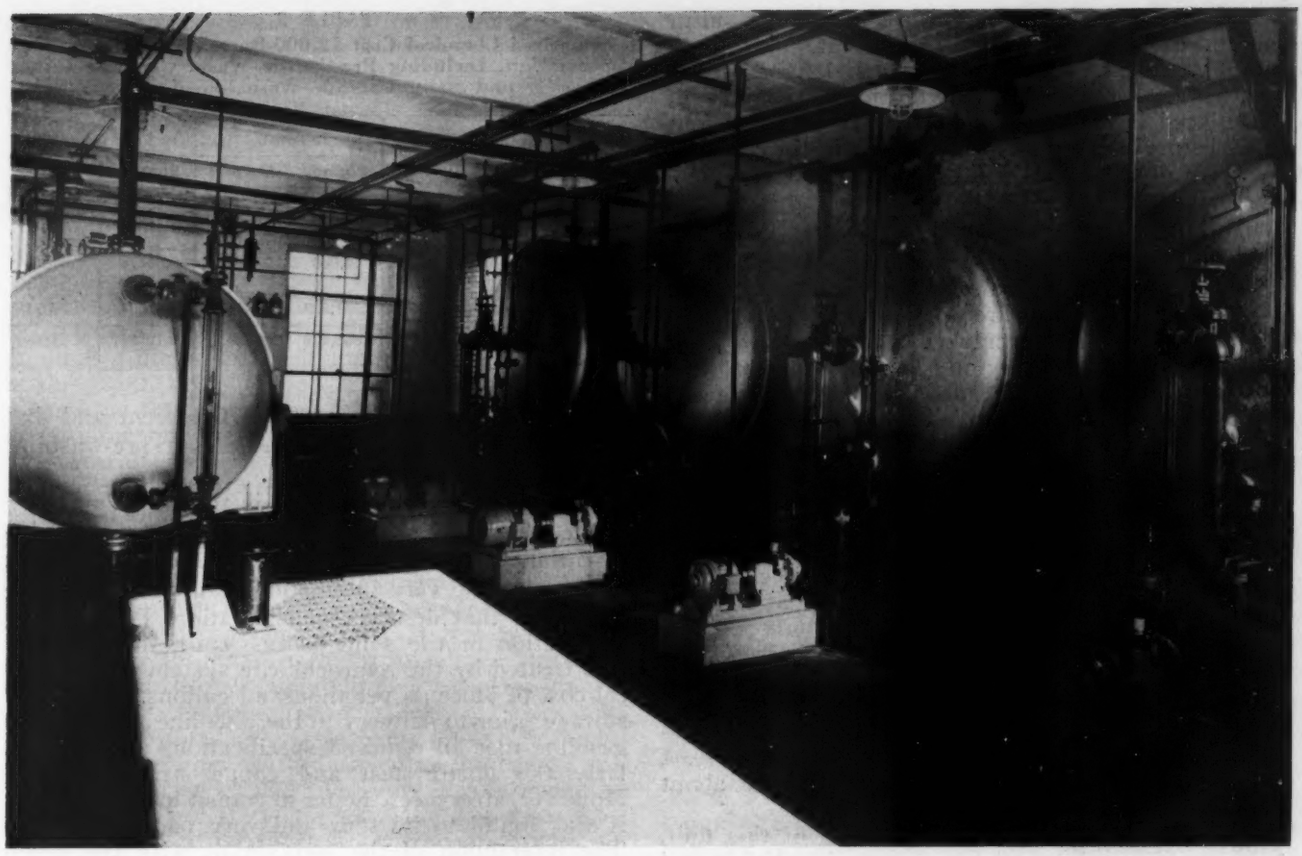
The use of glass-lined or enamel-lined steel separating tanks is another very marked improvement in the design and construction of liquid process units. These tanks are subjected to a 90-day test with copper solution by the fabricator to detect any defects prior to final installation. Inasmuch as these tanks may be operated as high as 50 pounds gauge pressure, they have many operating advantages over other vessels with lower operating pressures. The head-fin type supports eliminate the stresses accompanied by the cradle-type supports, or the like, used with ordinary steel tanks. This is an outstanding development in the manufacture of tanks of this type.

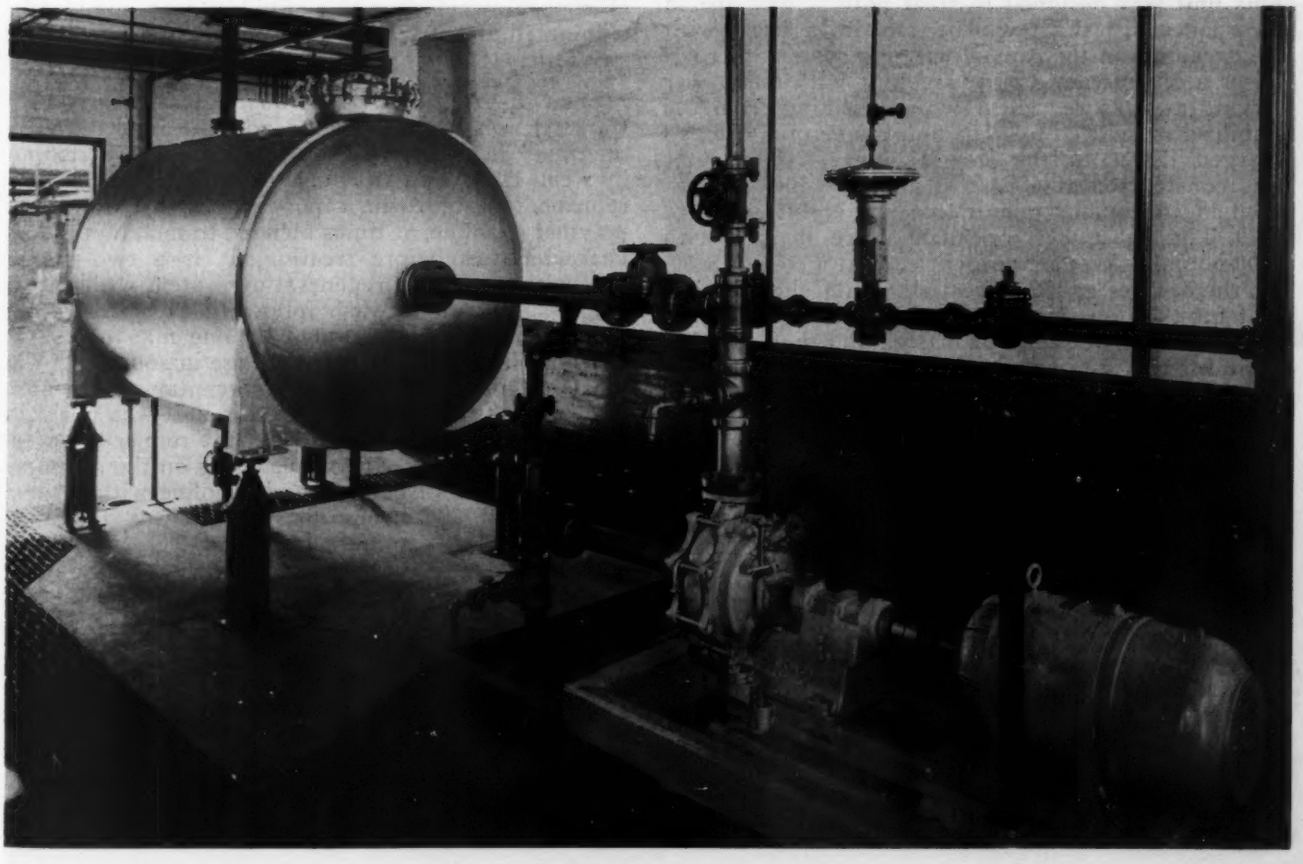
It is significant that during the construction of this unit, all of which was done by refinery labor except the concrete tanks, not a single piece of equipment was broken. When the completed unit was tested under pressure a minimum of leaks were observed. With the preparation of the copper solution and sulfide solutions completed, the unit was put on stream and turned over to the plant operators in less than a week.

This unit is attended by one operator per shift and processes cracked, reformed and straight-run gasolines. The operation to date has not been of sufficient duration to give any data as to chemical consumption. There is no loss of octane number or color, copper-strip corrosion tests are negative without exception, and the inhibitor requirements have been reduced on the average by 50 percent, and in some instances as much as 60 percent, over that required for the doctor-treating system formerly used.

Plant B—750-barrel-per-day solid-process unit: This unit was constructed in the early fall of 1937 and placed in operation in October of the same year. Since that time it has been treating straight-run gasoline from Michigan crude. It comprises a vertical caustic scrubber, a horizontal caustic settler with two hours settling time, an improvised gasoline heater to maintain a slightly higher temperature differential on the stream to the treating tower over that from the causic settler, an air-mixing chamber and two 4 x 10-foot treating towers, one of which serves as a spare. Each treating tower carries about three tons of solid-copper reagent, and throughputs have averaged 625 to 650 barrels per day. The gasoline enters the treating at 25 pounds, loses about 5 to 10 pounds pressure through the tower and goes directly to finished storage.

The gasoline processed in this unit is about a





Here are two views of a 1500-barrel Perco Liquid Copper Treating Unit. Above, the sodium sulfide wash systems are at the right with the copper solution-gasoline separator tank at the left. The unit is housed because of cold climate. Below, the copper solution-gasoline contactor is the right foreground and the separator tank at the left. In the right background is one outside wall of the concrete copper solution tanks.

350° F. end-point material, with a mercaptan sulfur content uniformly about 0.014 percent. This plant realizes reagent operationg cycles as long as seven months between reagent dehydrations. The reagent is replaced in the tower and re-used three or four times before being discarded. On this basis, chemical costs are of the order of 0.1 cents per barrel, exclusive of handling cost to and from the tower.

Plant C—25,000-barrel-per-day liquid-process unit: This unit embodies caustic washing systems for the several streams treated, a seven-unit copper-sweetening system, served by three regenerating systems. It is processing thermal cracked, thermal-poly, poly-reversion, vapor-recovery and straight-run gasolines and kerosene. The entire caustic washing and copper-treating systems are attended by one operator and one operator-helper per shift and a student operator on duty five days a week. The seven separate and distinct units normally treat four separate stocks simultaneously as the unit is so manifolded to receive and discharge the gasoline through any one or more of the individual units. On an 11-month check on chemical consumption, it was revealed that replacement for copper solution and sodium sulfide solution chemicals amounted to 0.218 cent per barrel. This cost is somewhat higher than that reported at some of the other plants described, and it is attributed to abnormal losses from the solution tanks. This gasoline ranges in sourness from probably 0.01 to 0.04 percent mercaptan sulfur, with an average of about 0.025 percent.

On a recent check on the operation of this unit, two sets of samples were taken at random before and after treating. Inspection of these samples of ethyl base and poly gasoline to and from the copper treater revealed the data in Table 1.

Plant D—50,000-gallon-per-day solid-process unit: This unit was designed to treat natural gasoline in accordance with the flow plan given in Figure 1, with the exception of the caustic washing system. It comprises a one-stream, two-tower unit with one tower serving as a spare. The raw feed coming from the stabilizer is reduced to 75 pounds gauge pressure and charged direct to the treating towers. This unit was constructed at a cost of about $2,500 and has been in continuous operation since early spring of 1939. The two towers originally were charged with 6300 pounds of copper reagent each at a cost of $697. On the basis of gasoline treated to date, the chemical cost for this unit is very nearly 2.3 cents per thousand gallons, or .1 cent per barrel, and the operating cycle for the original charge of reagent has not yet been completed. The mercaptan sulfur content

TABLE 1
Ethyl Base and Poly Gasolines—August 16, 1940

	Ethyl Gasoline No. 2 Treater		Poly Gasoline No. 5 Treater	
	To Treater	From Treater	To Treater	From Treater
Gravity	57.8	57.8	58.9	58.8
Reid vapor pressure	6.7	6.6	9.3	9.1
Color, Saybolt	27	27	30	30
A.S.T.M. octane No.	73.6	73.2	72.0	71.7
+1 cc. TEL	80.5	80.4	77.6	77.4
Copper-dish gum, mgm/100 cc.	34/38	54/56	242/266	175/169
Induction period, minutes	95	255	200	360
Distillation, °F.:				
First drop	101	100	105	106
10 percent	132	131	137	142
50 percent	218	215	224	226
90 percent	352	348	358	355
End point	405	404	397	398
Mercaptan sulfur, percent	0.016	.....	0.024	.....

TABLE 2
Summarized Chemical Cost 12,000-Barrel-Per-Day Solution-Process Unit, Including Pre-Caustic Wash, Copper-Solution and Sodium-Sulfide Wash Chemicals

	Total		Per Barrel	
	Pounds	Cost—$	Pounds	Cost—¢
1. Copper solution chemicals:				
Copper sulfate	159,480	$8,326.75	0.01935	0.10103¢
Sodium chloride	160,050	548.66	0.01941	0.00066
2. Sodium sulfide chemicals:				
Sodium sulfide	14,060	530.33	0.00170	0.00643
Caustic soda				
3. Caustic prewash chemicals:				
Caustic soda	551,529	14,844.78	0.06691	0.18011
Total chemicals	885,119	$24,250.52	0.10737	0.28823¢

ranges from 0.004 percent to 0.01 percent and due to the degree of stabilization no caustic pre-washing is required.

The operation of this plant is the part-time duty of the boiler-house attendant and his duties comprise essentially making a doctor test once each two hours.

There is one very interesting feature surrounding this plant that deserves consideration. Prior to the installation of the solid process unit, this gasoline was treated by the hyprochlorite system at a chemical cost of 52 cents per thousand gallons. In finished storage prior to delivery to the pipe-line terminal the gasoline met all required specifications and particularly the doctor test and copper-strip corrosion. However, after a few hours in transit in the pipe line it was found to be sour and very badly corrosive. The interaction of the mercaptans with the hypochlorite solution resulted in the formation of appreciable quantities of sulfur chlorides to the extent that even on short-time contact with the pipe-line metal the oil reverted to the sour and corrosive state. Immediately upon the installation of the solid process of copper sweetening this problem was completely eliminated and there has been no recurrence of it at any time.

Plant E—12,000-barrel-per-day liquid-process unit: Construction was completed and the unit put into operation in January, 1938. It is currently treating between 11,000 and 12,000 barrels per day of cracked, reformed, straight-run, vapor-recovery and catalytic-polymer gasoline, at times blended to final motor-fuel characteristics before treating. It is a two-stream unit with a common regenerating system with only a single-stage sulfide wash following each separating tank. This plant is operated by one man per shift. The gasoline streams treated range in sourness from 0.01 percent to 0.02 percent mercaptan sulfur content. About five months after this unit was put into operation a survey was made by the refiner to determine the effect of copper sweetening on the commercial production of house-brand gasoline with respect to tetraethyl lead. From this survey it was concluded that the savings in tetraethyl lead were very near 0.25 cubic centimeter per gallon, with only about 1.3 cubic centimeter per gallon being used in the finished gasoline. Since the cracked gasoline is acid-treated and rerun, no noticeable effect was observed on induction period and gum, however, it was not the practice to run induction periods beyond four hours, which the gasoline passed readily after treating by either the doctor or copper method and without the use of inhibitor. On several occasions raw cracked gasoline and catalytic polymer gasoline have been treated with complete satisfaction with no detectable

change in gum content, oxidation stability or lead susceptibility.

During a two-year period this unit treated approximately nine million barrels of gasoline for a total average chemical cost of 0.29 cents per barrel, including pre-caustic wash chemicals as summarized in Table 2.

One interesting feature of this plant that deserves consideration is that the spent caustic from the straight-run caustic washer is used as the sodium sulfide in the sulfide after-wash systems following both copper treaters. This practice has practically eliminated the necessity of purchasing sodium sulfide at this plant. From Table 2 it may be noted that the cost of the copper solution chemicals (copper sulfate and sodium chloride) is 0.01 cent per barrel, while the caustic pre-wash and sodium sulfide chemicals are approximately 0.19 cent per barrel. It has been estimated that this unit effected a savings of about 3.3 cents per barrel over the doctor treating system.

Plant F—10,000-barrel-per-day liquid process: This unit was constructed and put into operation about the first of the summer of 1940. It is a two-stream unit similar to Plant A described above and comprises pre-caustic-washing equipment and series sulfide-washing systems. It is currently processing cracked, reformed, vapor-recovery-plant and poly-reversion gasolines, with an average mercaptan sulfur content of about 0.025 percent. It is attended by one operator per shift and normally processes 8500 barrels per day. A typical set of inspection data before and after treating is given in Table 3.

Plant G—3000-barrel-per-day liquid-process unit: This unit was constructed at an estimated cost of $26,000 and was put into operation in the summer of 1939. Since its initial operation it has averaged processing a little more than 2100 barrels per day, operating only on a five-day schedule, with a total chemical consumption of 1800 pounds of copper sulfate, 1800 pounds of sodium chloride and 5400 pounds each of caustic and sodium sulfide. On the basis of the present prices of chemicals, this chemical consumption is equivalent to approximately 0.075 cent per barrel. The operation of this plant, including the caustic-washing system, is attended by one man per shift.

Prior to the installation of this unit, a pilot-plant investigation was made to determine the feasibility of the proposed unit. Pilot-plant run number one was made on a stock composed of 70 percent pressure distillate that had been acid treated and re-run and blended with 30 percent of a light virgin naphtha. Run number two was made on the raw pressure distillate of the same character, except for the acid treating and re-running, as that blended with the light virgin naphtha in run number one. These data, together with a typical set of data before and after treating through the commercial plant, are given in Table 4.

The data reported for the commercial plant in Table 4 was for a gasoline comprising 65 percent straight-run and 35 percent pressure distillate from a mixture of Mid-Continent and Venezuelan crudes that had been acid treated and re-run.

TABLE 3
Composite Dubbs Cracked, Thermal-Poly and Poly-Reversion Gasolines—August 19, 1940

	Before Copper Sweetening	After Copper Sweetening
Gravity, °API	57.9	57.8
Reid vapor pressure	6.25	6.15
Color, Saybolt	28	28
Octane number, A.S.T.M.	66.9	66.7
+ 1 cc. TEL	74.8	74.5
+ 2 cc. TEL	80.2	80.1
Gum, A.S.T.M. (mgm/100 cc.)	1.6	1.4
Copper-dish gum (mgm/100 cc.)	28.4	26.1
Induction period, hours	3¾	5
Distillation, °F.:		
First drop	110	116
10 percent	153	151
50 percent	238	237
90 percent	369	366
End point	416	418

Conclusions

The copper sweetening processes described unquestionably prevail in economy, and quality of product and simplicity of operation over doctor treating. As motor-fuel specifications improve, and particularly as anti-knock requirements increase, monetary savings from these processes will be correspondingly increased. Copper sweetening is more versatile in its application to various types of gasoline stocks and, therefore, does not require the technical control and readjustment necessary in doctor-sweetening units. Copper-treating units, with respect to cost and return on investment, compare favorably with other types of refinery equipment, being substantially equal in quality and serviceability.

TABLE 4

	PILOT PLANT DATA				Commercial Plant Data	
	Run No. 1		Run No. 2			
	Before Copper Sweetening	After Copper Sweetening	Before Copper Sweetening	After Copper Sweetening	Before Copper Sweetening	After Copper Sweetening
Gravity, °A.P.I.	61.8	61.9	56.9	56.8	57.0	57.1
Reid vapor pressure	9.45	9.45	11.00	10.30	9.60	9.70
Total sulfur, percent	0.061	0.061	0.252	0.251	0.093	0.093
Mercaptan sulfur, percent	0.003	Sweet	0.082	Sweet	0.005	Sweet
Color, Saybolt	30+	30+	Yellow	Yellow	30+	30+
Gums, mg./100 cc.:						
A.S.T.M.					1	1
Copper-dish					1	1
Induction period, minutes					300+	300+
Corrosion at 122° F.		Neg.		Neg.		Neg.
Distillation, °F.:						
First drop	90	90	87	84	92	91
10 percent	137	135	128	126	132	131
50 percent	227	229	283	283	207	207
90 percent	354	354	389	386	317	320
End point	410	405	419	415	404	398
A.S.T.M. octane No.	68.1	68.1	71.2	71.0	64.5	64.5
+ 1 cc. TEL	75.6	75.7	75.0	75.0	71.4	71.4
+ 2 cc. TEL	79.2	79.2	77.6	77.7	76.2	76.2

Water Pressure Speeds Removal Of Spent Catalyst

RECENTLY while removing spent acid catalyst from towers of the polymerization plant, workmen decided to try washing out loose pieces by water pressure. A section of half-inch pipe was attached to high-pressure-water hose and the pipe inserted after the bed had been drilled from the bottom upward, common catalyst removal practice.

Ease of washing out loose pieces prompted a trial of water pressure for starting the removal process. The next time the catalyst had lost its efficiency, the pipe was pushed upward through the catalyst bed, while water flowing through the nozzle at the top until the bed was penetrated. Then an operator climbed to the platform at the top of the column where the upper head had been removed, and inserted the pipe downward through the hole.

When the pipe end was thrust sharply against the sides of the hole, it was found that the water caused the material to slough from the walls. By working from the base upward, then thrusting the pipe downward through the bed, the material was loosened by hydraulic action as well as by prying through crevices formed after pieces had been dislodged. As soon as the hydraulically formed hole had been sufficiently enlarged, it was not difficult to break down the cemented material.

The equipment necessary for removing the catalyst with water consists of a hose of sufficient length to run from a convenient fire hydrant, or water pump, a one half-inch pipe long enough to reach through the vertical section of the catalyst. If the inside of the hose is the same as the outside diameter of the pipe, the connection may be made with an ordinary hose clamp, tightly compressed to prevent slipping when water pressure is applied. The pipe is more convenient for starting the initial hole when it is in two sections, as the space beneath the columns is never equal to the length of the columns themselves. Thus, after the hole has been started, the extension may be made to complete drilling to the top of the bed. Light steel barrels are used to catch the granular material as it flows with the water from the columns. Holes are punched in the side of the barrel so that the water will flow down the disposal ditch while the solid particles remain in the drum. Empty drums from which the last charge of material was removed are employed to catch the spent catalyst.

Using water under high pressure to remove spent catalyst from a UOP Polymerization unit. Half-inch pipe, long enough to reach the full length of the column, is attached to the plant water system through rubber hose.

In this plant, it is more convenient to cut a shallow trench from the base of the columns to the plant drainage canals to lead the water from the premises. Ordinary hydrated lime is sprinkled over the ground and in the trench to neutralize the acid to prevent harm to feet and shoes. A bucket containing an aqueous solution of bicarbonate of soda is placed at a convenient point near the scene of operations in which the operator may occasionally wash his hands to prevent damage to the skin, and to remove traces of the phosphoric acid with which he may come in contact.

Obviously, there is no opportunity to inspect the catalyst as it is washed from the bed to determine if there are sections that might be in condition to be reused, but, by calculating the quantity of polymer gasoline produced, it is not difficult to determine the condition of the bed as a whole. By balancing the saving in time by the new method against the possibility of recovering some small amount of nearly spent material, it appears that cleaning the columns by hydraulic action represents a distinct saving. The time required between starting the job of cleaning when the gases are cut out of the column and starting the gases back again after the fresh bed has been placed above the gravel support has never consumed more than three hours, and frequently a column has been reconditioned within as short a time as two hours.

Solutizer Sweetening and Gasoline Stability

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THE present article on the solutizer process discusses the general aspects of gasoline stability, and the effect of solutizer sweetening in particular. In evaluating the influence of any treating process on stability, it is important to separate the effect of the particular process itself and the effect of natural inhibitors that may be present. A method for doing this is presented, based upon the "basic inhibitor susceptibility" of the gasoline.

Solutizer sweetening preserves the inhibitor susceptibility, whereas many other sweetening methods cause a degradation in this property due to the introduction of deleterious by-products.

Gasoline sweetened with a "mixed" type solutizer solution (contains both isobutyrate and alkyl phenolate salts) will have a definite alkyl phenol content because of the equilibrium established with the alkyl phenol salts in the solutizer solution itself. In many cases, this equilibrium alkyl phenol concentration in treated gasoline is more than sufficient to assure adequate stability.

Two new commercial solutizer plants, just beginning operation in California, will utilize a "mixed" type solutizer solution to sweeten full range cracked gasoline.

THE solutizer process marks a distinct advance in gasoline sweetening because the mercaptans are removed completely from the gasoline, instead of being converted to disulfides with the accompanying traces of polysulfides or soluble metal salts. The treating agent employed in the solutizer process is a strong caustic solution to which has been added a suitable organic material, termed a "solutizer," and this results in a caustic solution of "high solvency power" for mercaptans. Previous publications[1] have discussed the underlying theory of the process, the extraction and regeneration steps, the attractive improvement in octane number and lead susceptibility as compared to the untreated sour gasoline, pilot-plant studies, and finally the operation of a 15,000-barrel-per-day commercial plant at the Wood River refinery of Shell Oil Company, Incorporated. In this paper we wish to discuss the effect of solutizer sweetening on the stability characteristics of the gasoline, with particular emphasis on the inhibitor susceptibility.

Stability of Cracked Gasoline

The stability of a cracked gasoline may be considered as arising from two main factors: (1) inhibitors, and (2) refining. The role played by oxidation inhibitors, either the natural alkyl phenols or the various synthetics, is a very important one, and indeed, can hardly be over-emphasized. There is evidence to believe that refining processes such as acid or clay treating improve stability by conditioning the gasoline so as to improve its response to the action of inhibitors. This of course is done by polymerizing and removing the more unstable gasoline constituents. The importance of inhibitors becomes evident through the fact that we have never encountered a cracked gasoline, no matter how severely refined, that will pass the conventional stability tests after all of its inhibitor has been removed from it.

Now in evaluating the influence of a given treating process on the stability characteristics of a cracked gasoline, it is important to be able to separate the effect of the particular process itself, and the effect of the natural inhibitors that may be present. Changes brought about simultaneously in the natural inhibitor content of the gasoline and in its stability often may obscure the real effect of the treating process, and may lead to erroneous conclusions. Failure to adequately take this factor into account has lessened the value of much published work.

In order to eliminate this troublesome variable, Newton,[2] in his study on acid treatment, resorted to the diazo reaction in an attempt to obtain gasoline samples entirely free of natural inhibitors. The induction period of the inhibitor-free gasoline apparently was used as the criterion for gauging the degree of refining obtained. A limitation of the diazo reaction, pointed out by Newton,[2] is that not all phenols will react in this manner, especially those that contain groups substituted in all three ortho and para positions.

In studying the stability of cracked gasolines, we have employed a particular solutizer solution in the laboratory to obtain inhibitor-free samples, and this procedure appears to be more effective for this purpose than the diazo reaction, as will be shown further below. Known amounts of given inhibitors are then added to the completely *uninhibited* gasoline and their effect on the induction period is determined. Such a procedure allows the evaluation of what we have called the "basic inhibitor susceptibility" of the gasoline in question, and the true effect of a given treating process on this property may therefore be readily determined. The susceptibility of a gasoline to inhibitor is a most important property, not only from the standpoint of actual inhibitor requirement, but also because it goes hand in hand with other stability characteristics of the gasoline. Indeed, we can go so far as to say that any treating process that improves the basic inhibitor susceptibility of the gasoline has also improved other stability properties; conversely,

a decrease in the basic inhibitor susceptibility means an impairment of the gasoline stability.

Removal of Natural Inhibitors in the Laboratory

The data of Table 1 show the extent to which natural alkyl phenol inhibitors may be removed with the diazo reaction and with our K-2 solutizer solution. The gasoline employed in these experiments was an acid-treated and doctor-sweetened full-range cracked gasoline. The diazo procedure was carried out according to the directions given by Newton.[2] The solutizer treatment was performed by cooling the gasoline to O° C. and extracting in a separatory funnel with 10 percent volume of precooled K-2 solutizer (6N potassium hydroxide—3N potassium isobutyrate). It will be noted in Table 1 that one solutizer treatment removed almost all of the natural inhibitors from the gasoline and complete removal was obtained by two such treatments. Three diazo treatments, on the other hand, did not remove all the natural inhibitors, and the induction period of the resultant gasoline was even slightly higher than that of the sample treated but once with K-2 solutizer. In the laboratory, two 10 percent volume extractions with the K-2 solution are generally employed to insure complete inhibitor removal. Because of its instability due to the absence of inhibitors, it is important to test or to reinhibit the K-2 solutizer treated gasoline immediately.

TABLE 1

Removal of Natural Inhibitors from a Cracked Gasoline with the Diazo Reaction (2) and with K-2 Solutizer Solution*

Number of Successive Treatments	INDUCTION PERIOD, MINUTES†	
	After Diazo Treatment	After Solutizer Treatment
None	395	
1	95	25
2	45	15
3	30	15
1 Diazo Followed by 1 Solutizer	15	

* 6N potassium hydroxide—3N potassium isobutyrate.
† At 100 °C. and 100 pounds oxygen gauge in U.O.P. type bombs. A 30 minute correction has been subtracted from the observed induction periods to correct for the heating up lag of the gasoline in the bombs.

The data of Table 2 are presented in order to show that the complete removal of inhibitors by the K-2 solutizer treatment has no other effect on the stability properties (except also to sweeten the gasoline simultaneously if it is sour). In these experiments a portion of the same gasoline used above was K-2 solutizer treated and then inhibited with 50 mg./100 ml. of 4T inhibitor. The 4T material is an alkyl phenol type inhibitor. The inhibited gasoline sample was then successively extracted with K-2 solutizer and reinhibited. Comparing items 3, 5, 7, and 9 of Table 2, it is seen that the effectiveness of a given amount of 4T inhibitor in this gasoline is not changed even by four solutizer extractions followed by reinhibition in each case.

Influence of Sweetening on the Inhibitor Susceptibility

Data are presented in Table 3 for several different cracked gasolines, showing the effect of solutizer sweetening and plant doctor sweetening on the basic inhibitor susceptibility. In these experiments the sour and the corresponding plant doctor-sweetened gasolines were treated with K-2 solutizer which removed all natural inhibitors and simultaneously sweetened the sour gasoline. The effectiveness of known amounts of 4T inhibitor in the completely *uninhibited* samples was then determined. As shown in Table 3, the susceptibility of the solutizer treated gasolines was much greater in every case than that of the doctor-treated gasolines. In order to reach an induction period of 300 minutes, starting with the uninhibited samples, the various solutizer sweetened gasolines required only from 49 to 78 percent as much inhibitor as the doctor-treated gasolines.

TABLE 2

Removal of Inhibitors from a Cracked Gasoline by Solutizer Treatment, followed by Reinhibition

Item No.	GASOLINE TREATMENT	Induction Period, Minutes
1	None—Original Gasoline	395
2	Item (1), K-2 Solutizer Treated*	25
3	Item (2), plus 50 mg./100 ml. of 4T Inhibitor	455
4	Item (3), K-2 Solutizer Treated*	20
5	Item (4), plus 50 mg./100 ml. of 4T Inhibitor	465
6	Item (5), K-2 Solutizer Treated*	20
7	Item (6), plus 50 mg./100 ml. of 4T Inhibitor	455
8	Item (7), K-2 Solutizer Treated*	20
9	Item (8), plus 50 mg./100 ml. of 4T Inhibitor	455

* One 10% vol. batch extraction.

Solutizer treating may be considered as a mild refining since it removes mercaptans from the gasoline. However, it is likely that the reason for the higher inhibitor susceptibility of solutizer-sweetened gasoline is to be attributed largely to the fact that no deleterious products are introduced during the course of sweetening. Solutizer sweetening therefore preserves the inhibitor susceptibility and other stability properties of the gasoline, while many other sweetening methods bring about a degradation in these properties.

"Mixed" Solutizers Leave Natural Inhibitors in Gasoline

From a practical point of view, the presence of alkyl phenols in gasoline is desirable, and we wish to retain at least a portion of them in the treated product. This is done by employing a so-called "mixed" solutizer which contains both isobutyrate and alkyl phenolate salts. A typical solution of this type, designated as K-20, has the following composition: 6N free KOH—1.5N potassium isobutyrate—13.5 percent volume alkyl phenol (as the salt). The gasoline sweetened with such a solution contains a

TABLE 3

Effect of Solutizer Sweetening and Plant Doctor Sweetening on Basic Inhibitor Susceptibility of Several Cracked Gasolines
(Sour and plant doctor sweetened gasolines extracted with K-2 solutizer to remove all inhibitors and to sweeten the sour gasoline. Known amounts of 4T inhibitor then added to completely uninhibited samples.)

Gasoline No.	Conc. of 4T Inhibitor Added Back to Uninhibited Gasolines, mg./100 ml.	Induction Periods at 100 °C. and 100 Lbs. Oxygen, Minutes		Amount of 4T Inhibitor Required in Uninhibited Gasolines for a 300 Minute Induction Period, mg./100 ml.		Ratio of Inhibitor Requirements, Solutizer Sweetened to Plant Doctor
		Sweetened by Solutizer	Sweetened by Plant Doctor	Sweetened by Solutizer	Sweetened by Plant Doctor	
1	0	10	10	28	51	0.55
	20	235	145			
	40	375	250			
2	0	35	25	14	18	0.78
	20	380	325			
	40	605	570			
3	0	10	10	18	37	0.49
	20	330	180			
	40	520	320			
4	0	15	15	20	31	0.51
	20	300	200			
	40	525	375			

more or less definite amount of alkyl phenols because of the equilibrium established with the alkyl phenol salts in the solutizer solution itself. Experiments have shown that this equilibrium amount of alkyl phenols in the gasoline is about 0.02 percent volume for the K-20 solutizer. The effectiveness of this amount of alkyl phenol as an inhibitor in a given gasoline depends on the inhibitor susceptibility. This latter property is of course affected by the extent of the previous refining of the gasoline, the presence of certain deleterious impurities, the gasoline composition, etc. In many cases, the amount of alkyl phenols imparted by the K-20 solution may be more than sufficient to assure adequate stability. In the case of some poorly treated gasolines it may be necessary to add further amounts of inhibitor. This is illustrated by the data of Table 4 which gives the induction periods of a number of sour cracked gasolines, before and after treatment with the K-20 solution at room temperature. As expected, there is no relation between the induction period of the untreated and the solutizer treated gasoline, since the latter is dependent essentially on the inhibitor susceptibility of the gasoline. It will be observed that the induction periods of the treated samples range from 100 minutes to as high as 740 minutes. The properties of the gasolines of Table 4 are listed in Table 5.

In the commercial application of the solutizer process, we therefore use a solution of the mixed type

TABLE 4

Effect of Treating with a "Mixed" Solutizer (Contains both Isobutyrate and Alkyl Phenolate) on the Induction Period of Cracked Gasolines

Item No.	INDUCTION PERIOD AT 100 °C. AND 100 LBS. OXYGEN, MINUTES	
	Untreated Sour Gasoline	After Treatment with K-20 Solutizer
1	40	525
2	70	315
3	75	100
4	75	185
5	75	740
6	95	225
7	110	355
8	125	335
9	150	260
10	270	220
11	305	300
12	315	130

TABLE 5

Properties of the Gasolines of Table 4

Item No.	A.S.T.M. Distillation, °F.					A.P.I. Gravity	Bromine No. (3)	Sulfur, % Wt., of Sour Gasoline	
	I.B.P.	10%	50%	90%	F.B.P.			Total	Mercaptan (4)
1	99	126	198	268	302	68.9	98	0.31	0.057
2	84	114	216	360	414	71.1	157	0.14	0.045
3	109	158	260	354	389	57.9	92	0.13	0.037
4	99	127	241	378	410	59.8	91	0.14	0.022
5	102	136	244	351	383	61.3	77	0.14	0.015
6	92	131	239	339	378	62.5	83	0.28	0.111
7	108	145	246	311	334	62.3	91	0.45	0.041
8	111	164	259	353	388	60.7	38	0.09	0.016
9	97	154	271	379	408	58.3	60	0.03	0.005
10	117	165	255	361	412	58.1	55	0.04	0.004
11	105	145	241	332	377	60.9	46	0.09	0.022
12	95	131	237	331	363	63.7	91	0.64	0.173

when treating full-range cracked gasolines in order not to extract all of the natural inhibitors from the gasoline. When treating straight-run gasolines, a straight isobutyrate solution (such as K-2) is employed. Low-boiling cracked gasolines or reformed gasolines that contain no natural alkyl phenol inhibitors are often treated with the straight isobutyrate solution and then inhibited or blended with gasolines that do contain natural inhibitors. The 15,000-barrels-per-day solutizer plant at Wood River uses the K-2 solution to treat a blend of full-range reformed and light cracked and straight-run gasolines. The treated material is blended with a heavy cracked gasoline that contains natural alkyl phenol inhibitors. Two new plants about to begin operation at the Martinez and Dominguez (California) refineries of Shell Oil Company, Incorporated, will treat full-range cracked gasoline and will employ a mixed type solutizer solution for this purpose.

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[2] Newton, J. Inst. Petr., **25**, 24 (1939)
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Continuous Catalytic Cracking Process Announced

A NEW catalytic cracking process has been announced by Standard Oil Company (New Jersey). W. S. Farish, president of the company, and F. A. Howard, head of Standard Oil Development Company, have disclosed that high-octane motor fuel is soon to be pouring from commercial units embodying the process. Three large plants are to be built at the Bayway, New Jersey, refinery of Standard Oil Company (New Jersey), the Baton Rouge, Louisiana. refinery of Standard Oil Company of Louisiana and the Baytown, Texas, refinery of Humble Oil & Refining Company. The Baton Rouge plant is expected to be in operation this year.

The unique feature of the Jersey process is the use of a "fluid catalyst." The catalyst does not remain stationary in a reactor chamber which must periodically be taken out of operation while deposited coke is burned off, but flows along in intimate admixture with the oil stream passing through the catalytic system. Although a detailed description of the process has not yet been disclosed, the following account covers the main principles.

Operation

The first step in the process consists of heating and vaporization of the feed stock. The feed is pumped through a furnace where heating and vaporization occur. As the vapors emerge from the furnace a stream of catalyst in finely powdered form is fed into the vapor transfer line, and the mixture then flows on into the bottom of a chamber where, as the mixture rises, the catalytic cracking reaction takes place. The cracked vapors and catalyst pass from the top of the chamber and enter a device known as a "cyclone" separator." Here the catalyst, containing coke and tarry matter produced in the cracking operation, is separated from the oil vapors. The catalyst then is discharged into a regeneration chamber, where the substances on the catalyst are burned off by means of air. There is a continuous passage of spent catalyst into this chamber and emergence of regenerated catalyst from the chamber. The regenerated catalyst then passes into a system from which it is once more fed into the transfer line carrying the vapors from the furnace.

The vapors leaving the cyclone separator, consisting of gas, gasoline and gas oil, pass on into the fractionation section of the unit, where the products are fractionated by the usual methods.

Obviously, the process is continuous throughout. It is a single-pass operation, for the gas oil which is produced is not recycled through the furnace with the fresh feed for further cracking. Ordinarily it would be used for blending purposes or thermally cracked elsewhere in the refinery.

Data on operating temperatures and pressures have not yet been disclosed. However, it was disclosed that the pressure is low, not being more than three or four atmospheres.

Feed Stocks and Products

The catalytic cracking process utilizes distillate feed stocks in order to eliminate undesirable salts that would impair the activity of the catalyst. If the process is used to convert a reduced crude, the residuum first is heated and flashed in an evaporator which permits the very heavy constituents to pass as a liquid from the base of the evaporator and provides the vaporized portion as feed stock for the cracking process.

The Jersey process is designed primarily for the production of motor fuel. This gasoline has an octane number of 78 to 82 C.F.R.-M. or 92 to 96 C.F.R.-R. A yield of about 50 volume percent of 400-end point gasoline, based on the charge to the catalytic unit, is obtained. The gasoline is relatively high in olefins, the percentage of these unsaturated hydrocarbons depending on operating conditions. The total aromatic content, which also varies, may reach 10-12 volume percent of the total gasoline. But little treatment is needed to make the gasoline satisfactory for use in motor-fuel blends. The high octane number of this material obviously makes it a particularly desirable constituent for such blends, because it can be used in conjunction with gasolines of relatively low octane number and may reduce the amount of knock inhibitors used in motor blends.

Characteristics of the gas oil produced in the Jersey catalytic cracking process have not been disclosed. The material is not as satisfactory as virgin gas oils for cracking purposes but undoubtedly can be used profitably as a charge stock for thermal cracking.

The small amount of tar and coke produced in the cracking process is not recovered, being burned from the catalyst as previously described. The gas made in the operation is either used as fuel or processed for the recovery of hydrocarbons used in various synthetic processes.

No data on investment and operating costs for the Jersey catalytic cracking process are available. Farish declared that all Standard Oil Company (New Jersey) patent rights dealing with catalytic cracking, and with hydroforming (catalytic naphtha reforming) as well as licensing rights in these fields previously brought from other interests have been acquired by Standard Catalytic Company (formerly the Standard-I. G. Company) which is a wholly-owned subsidiary of Standard Oil Company (New Jersey). Standard Catalytic Company has made working arrangements for the licensing of these patents to the petroleum industry through M. W. Kellogg Company and Universal Oil Products Company.

The Study of Water Problems in Atmospheric Cooling Systems

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SOLUTION of problems in atmospheric water cooling systems in petroleum refining is receiving closer attention today because expansion of processes and consequent increased demands of cooling have stimulated the trend toward water conservation through the installation of re-circulating water systems.

Problems occurring in these systems are influenced by atmospheric contamination from gases, such as oxygen, carbon dioxide and hydrogen sulphide, bacteria, algae, and dust which frequently introduces appreciable amounts of silica into the equipment. Velocity, temperature and incomplete wetting of metal surfaces are design features and a variety of metals and alloys present in systems encourage and introduce water problems inherent to the systems, unless corrective treatments are employed.

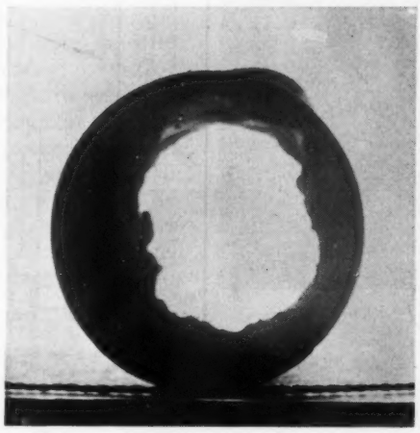

FIGURE 1
Pipe clogged with iron bacteria.

Corrosion occurs commonly in atmospheric cooling systems because of the repeated aeration of the water. The problem is not solved conveniently by oxygen removal because of this fact. The high velocities present in condensers and of connecting rods of internal combustion engines accelerate the corrosion rate. The rate of corrosion is increased still further by the multiplicity of voltaic couples normally present in large cooling systems.

Living organisms are a serious problem in cooling systems and algae, bacteria, or both may be factors responsible for scale, corrosion, or simply slime found on heat transfer surfaces. Aside from repeated contamination due to atmospheric contact, the property of many of these organisms of developing resistance to unfavorable environments, including chemicals intended to destroy them, is a difficult and disconcerting factor in their control.

Complex Problem

Aside from the algae with which we are familiar, two types of bacteria are particularly troublesome. One of these is the sulfur bacteria which decompose sulfates to sulfides accelerating corrosion. The other is iron bacteria which have clogged piping (see Figure 1) completely in samples coming to our attention and which often are confused with corrosion to which they bear no important relation. The importance of microscopic examination of deposits from cooling systems needs to be stressed in this connection.

Scale is a problem in cooling systems and while carbonate deposits are most common, both silica and sulfate deposits occur with regularity. Temperature conditions in much heat-transfer equipment are high enough to cause appreciable deposition. Silica deposits in exhaust valve jackets of internal combustion engines and in condensers operating with high skin temperatures are not unusual. Corrosion products, bacterial and algal deposits are grouped with scale sometimes, but we believe these should be regarded more definitely with reference to their source in order to distinguish between cause and effect.

The scale, corrosion and organism problems of the atmospheric cooling system differ from the same problems of other types of equipment. In addition to the chemical character of the make-up water and the mechanical environment of temperatures, pressures and velocities produced and controlled at will, a variable concentration or evaporation rate and a variable degree of atmospheric contamination present themselves. Both of the latter factors are dependent upon atmospheric conditions and climatic and seasonal changes also manifest themselves in the operation and problems of the atmospheric cooling system.

The cooling-water problem is influenced still further by the large volumes of make-up required which serves as a limiting economic factor in the corrective treatment approach. In addition, many of the raw waters used to supply these systems are of a quality which would not be considered for use in other types of water-using equipment. Aside from the trite facts that certain compounds deposit scale and others accelerate corrosion, the information obtained from experiments with other types of systems, such as boilers and once-through systems is not of particular value or pertinent in studying atmospheric cooling system water problems.

For the past several years, our laboratories have been studying atmospheric cooling-system water problems, both in connection with product development and application and in cooperation with large-scale cooling-system operators who understand

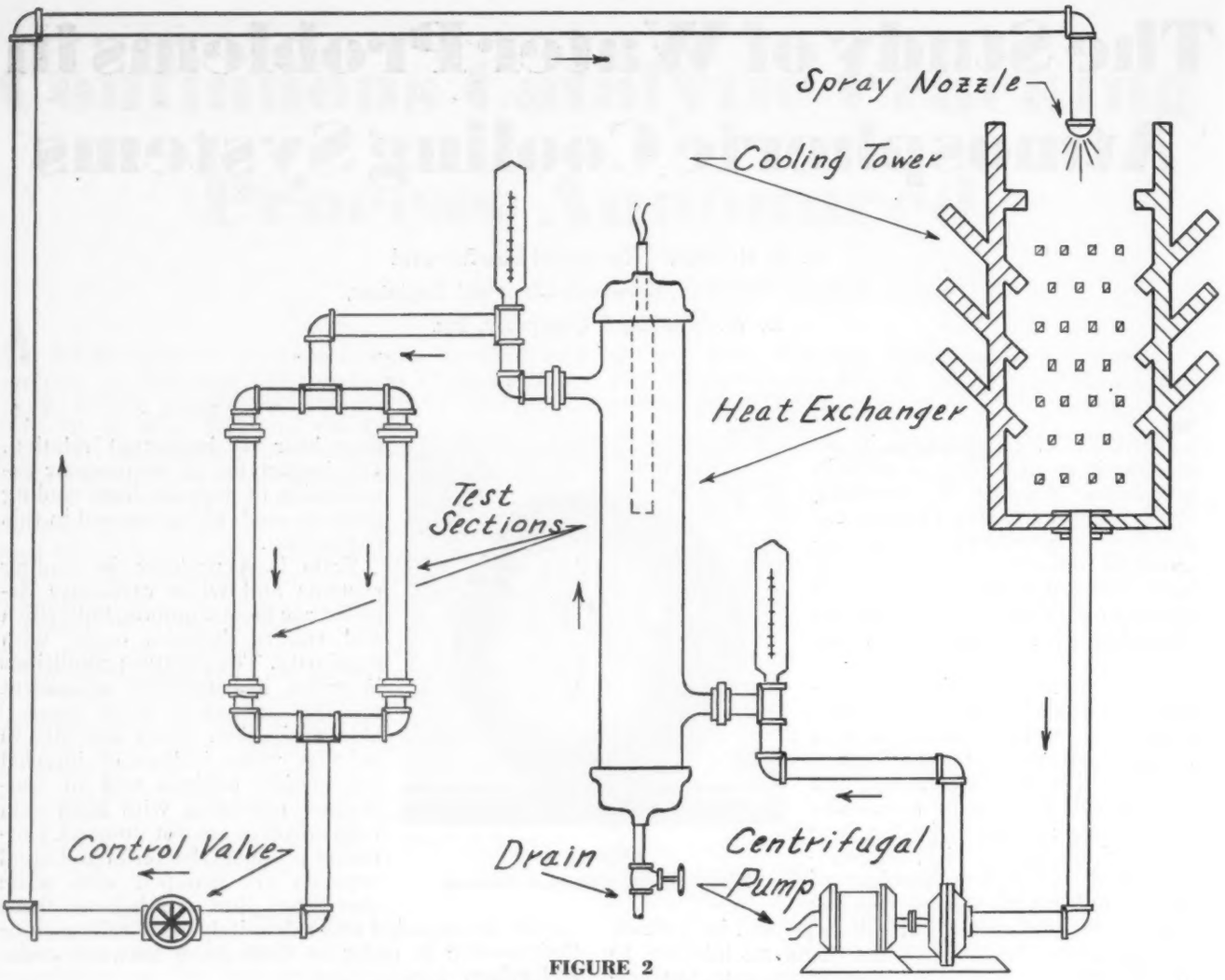

FIGURE 2
Arrangements of units and piping in laboratory cooling system.

the need for a scientific approach to the problems of this field. Reference to the literature discloses a definite lack of information on the critical concentrations of various elements and compounds in their relation to scale, corrosion, and effect on corrective chemicals employed for treating.

Field Interpretations

There are several phases to the study of water problems in this field. Probably the primary step taken in such studies is in the field where equipment may be examined and the effects of the water observed and recorded. Field observations must be recorded by experienced men whose interpretations will be accurate and whose observations include the effects of physical and design factors. The plant history with reference to water conditions, appearance of scale or corrosion and the results obtained with various chemicals also serves to provide information of interest and value. The importance of plant histories where reliable data may be obtained cannot be over-emphasized.

Where water conditions have been under some form of routine control, the statistical study of control data, plotting the relationships of various determinations and considering the time and load relationships to the problem at hand becomes most important. Records of unusual or exceptional problems solved in the past provide a guide to the future solution of similar problems.

In the laboratory, analyses of waters from the supply and the system disclose information of significance and the examination of scale and corrosion specimens becomes of vital importance. Quiescent and accelerated corrosion tests provide a guide to chemical inhibitors which may be of value, but do not duplicate operating conditions.

All of these methods of study may be criticized for failure to allow for controlled experimental conditions, or for failure to duplicate operating conditions sufficiently to permit the direct interpretation of results without the necessity of using plant operating equipment for at least partial experimental purposes.

In order that we may carry on accurate studies of these problems without being subjected to the inaccuracies and variables mentioned, we have installed laboratory cooling systems in our research department. By installing six identical systems to operate continuously under controlled conditions, we hope to produce a series of facts which will serve as a basis for an intelligent approach to atmospheric cooling system water problems by any water consultant.

The arrangement of apparatus we are utilizing for this purpose is shown in Figure 2. The water is heated by means of an electric immersion heater con-

tained in the heat-exchanger shell. Water is circulated from the heat exchanger over a cooling tower of laboratory scale, but of orthodox construction. Flow rates may be controlled by the needle valve, wind velocities by an exhaust fan and chemical conditions by the laboratory. Figure 3 indicates the actual installation of all six units. The electric immersion heaters are wired to warning lights and the failure of any heater will attract immediate attention. A top view of one of the towers, Figure 4, indicates clearly the atomization accomplished by the spray nozzles used.

A number of difficulties were encountered at the beginning of operations with the laboratory cooling systems. The failure of the small centrifugal pumps to operate longer than a few hours was an initial stumbling block. This was corrected by the use of heavier motors. More recently, however, a number of the pump shafts have sheared, introducing another problem which is receiving our present attention. Water-tight construction with a minimum of spray loss without resorting to closed construction required several efforts of an expert cabinet maker. The six original units have been replaced by new units of more satisfactory construction. At present, we believe that the units are in condition to operate satisfactorily for some time to come. The service claimed by the manufacturer of the electric immersion heaters is not being obtained, however.

Our initial efforts using these systems was based on the study of the effect of pH reduction on a specific corrosion problem. Difficulties with the systems interfered with that investigation, but the fact that pH reduction would be a costly item was given ample demonstration. While the results of this experiment were not of unusual significance, it was encouraging to observe that the results obtained checked exactly with data obtained by competent experts over a period of several years while the conditions at the plant concerned were being observed.

Our second study concerned scale control using a natural water which had never been treated internally with success. The data obtained on this run checks well with plant history and encourages us to believe that we are simulating plant operating conditions successfully in our apparatus with respect to scale and corrosion.

With Synthetic Water

Our third study followed the same general plan as the second study with the exception that a synthetic water was used for experimental purposes. The results obtained from this series of experiments are shown in subsequent figures and tables. The results emphasize several important facts, including a proven similarity of results obtained with natural and synthetic waters. It may appear that we are going to a considerable length in proving the relationship of this equipment to practical operating conditions, but we feel that this is an essential prelude to accumulating direly needed data on these systems.

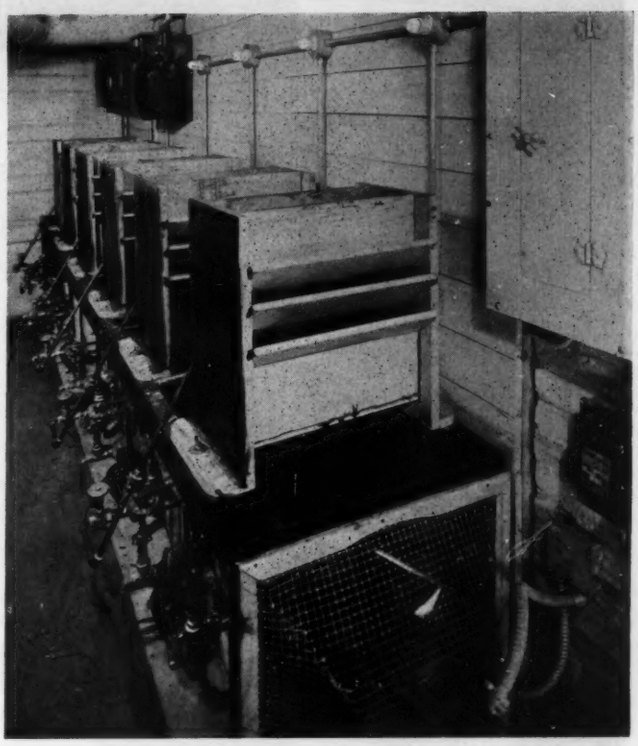

FIGURE 3
Six laboratory cooling systems.

Make-up water for this study was prepared by diluting a definite volume of synthetic concentrate which resulted in a water of constant composition and pH. The concentrate contained comparable amounts of all scale-forming chemicals found in natural waters. An analysis of the make-up water together with the analyses of waters taken from each tower at the completion of the study is given in Table 1.

The object of this study was two-fold: to determine the effect upon deposition of scale of (1) various chemical treatments, and (2) solids concentration. Conditions other than those affected by the two factors stated above were maintained equal and constant for all cooling systems. Total hours of operation were identical. A circulation rate of approximately five gallons per minute was maintained for all systems representing a complete turnover for each system approximately every one and one quarter minutes. An average inlet temperature of 103° F. and outlet temperature of 114° F. were maintained. Circulation created by a large ventilating fan provided equal atmospheric conditions.

Make-up water containing no treatment was circulated through Tower No. 1. This cooling system served as the primary basis of comparison for our third study. Towers Nos. 2 and 4 circulated make-up water containing a residual of 2 p.p.m. tetra phospho

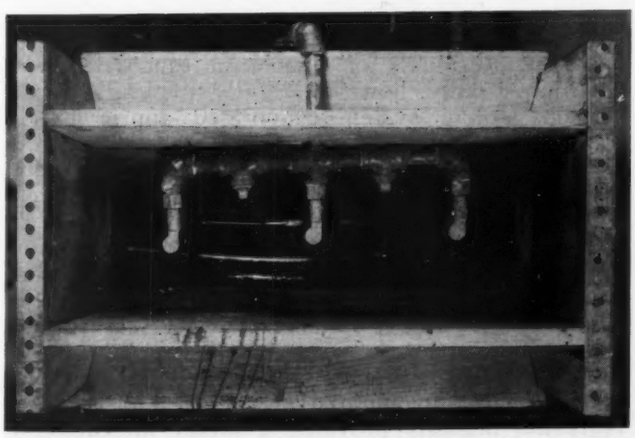

FIGURE 4
Top view of laboratory cooling tower showing spray header.

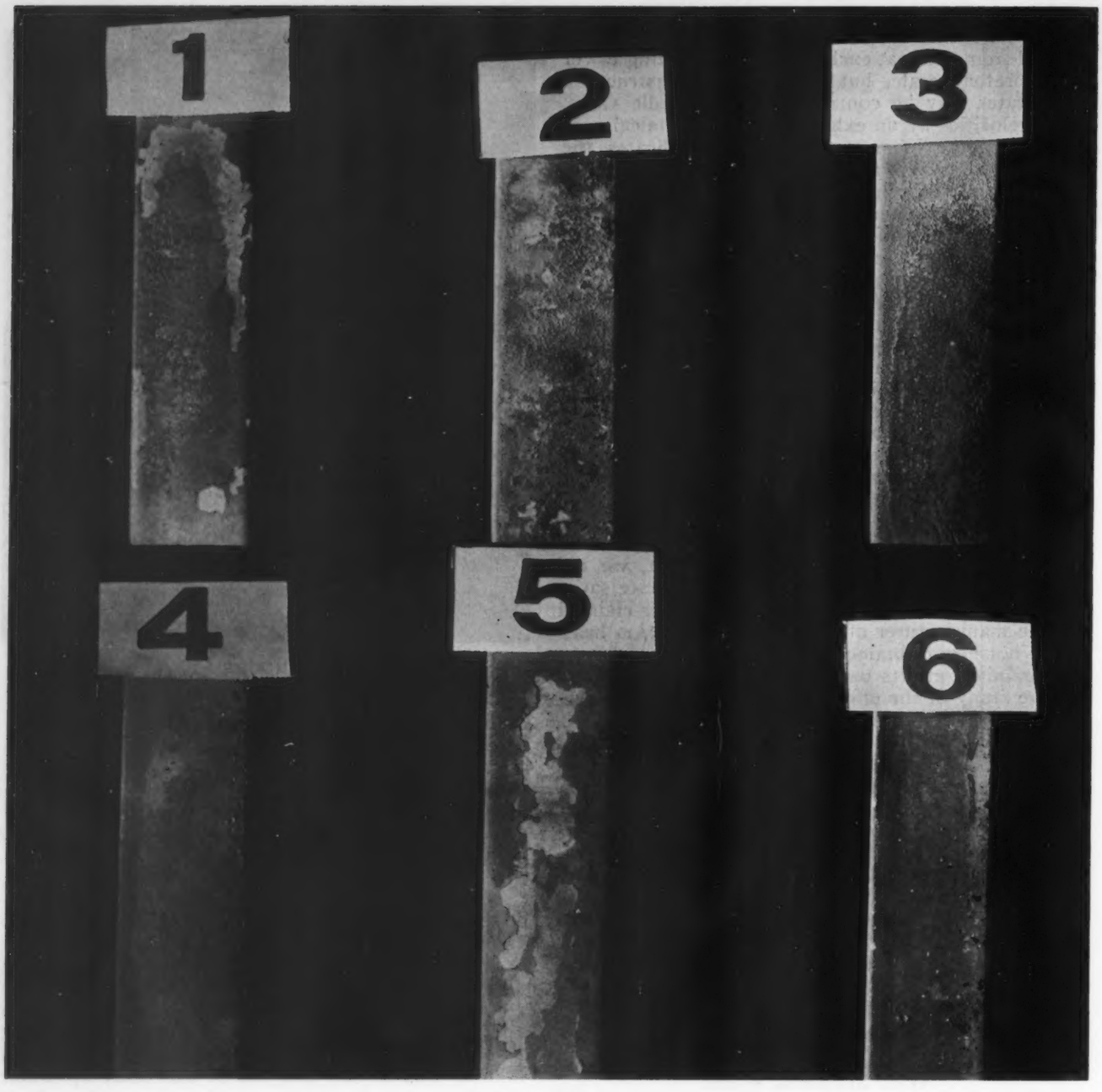

FIGURE 5

Immersion heater surfaces at end of experiment 5000 p.p.m. solids—(1) no treatment, (2) tetra phospho glucosate, (3) hexa meta phosphate; 3500 p.p.m. solids—(4) tetra phospho glucosate, (5) beta glucoside and (6) quachrom glucosate.

glucosate, the systems differing only in their content of dissolved solids. The solids content of Tower No. 2 was allowed to approach a limit of 5000 p.p.m. as a maximum while the solids content of Tower No. 4 was controlled to a maximum of 3500 p.p.m. Tower No. 3 circulated make-up water carrying a residual of 2 p.p.m. hexa meta phosphate with the upper limit of solids content set at 5000 p.p.m. Make-up water for Tower No. 5 contained 10 p.p.m. beta glucoside. The beta glucoside was added in this amount directly to the make-up water, as residuals of beta glucoside cannot be determined with the rapidity possible with other determinations. Tower No. 6 circulated water containing 10 p.p.m. quachrom glucosate. Again, the treatment was not controlled by determining treatment residuals, but by introducing the treatment directly with each addition of make-up. Residuals of quachrom glucosate were determined daily, however.

Each cooling system evaporated approximately eight quarts of water per day. The systems were replenished with make-up water four times daily and treatment residuals of Towers Nos. 2, 3 and 4 were determined before each addition of make-up. An observation of the tower level, indicating the volume of water in the system, plus the residual determination enabled the operator to calculate the required amount of treatment concentrate necessary for the maintenance of proper treatment residuals.

The fact that little possibility existed of the chloride ion being precipitated in the form of scale or corrosion deposits provided a factor indicative of the solids concentration of each system. Dissolved solids chloride ratios were calculated at the outset

P.P.M.	Make-Up Water	Cooling Water				
		Tower No.1	Tower No.2	Tower No.3	Tower No.4	Tower No.5
Hydrate	None	None	None	None	None	None
Carbonate	None	48.	120.	126.	132.	54.
Bi-Carb.	127.	243.	390.	372.	418.	266.
Carb.Diox.	3.	None	None	None	None	None
Chloride	43.	337.	355.	350.	334	344.
Sulphate	212.	1238.	1398.	1367.	1156.	1174.
Silica	10.6	24.	34.	29.	26.	40.
Calcium	35.	60.	102.	108.	110.	61.
Magnesium	12.	59.	65.	65.	61.	58.
Iron	0.2	1.1	1.2	1.7	1.1	1.8
Hard.(cak.)	135.	392.	521.	537.	525.	391.
Hard. Soap	95.	320.	365.	390.	360.	320.
Alkalinity	127.	391.	510.	498.	550.	320.
Acidity	2.0	None	None	None	None	None
Tot. Solids	539.	3720.	4224.	4238.	4137.	3892.
Susp.Solids	None	104.	32.	12.	144.	101.
Dis.Solids	539.	3616.	4192.	4226.	3393.	3791.
Vol.& Org.	46.	365.	477.	528.	541.	634.

STUDY No. 3

TABLE 1
Analyses of make-up water and cooling system waters at end of experiment.

Per Cent	Deposit				
	Tower No.1	Tower No.2	Tower No.3	Tower No.4	Tower No.5
$CaSO_4$	3.20	3.22	3.35	3.53	3.36
SiO_2	3.66	1.48	1.70	1.58	1.35
$CaCO_3$	42.31	49.49	48.15	44.51	41.40
$MgCO_3$	16.86	19.75	21.80	23.66	15.15
Fe_2O_3	7.62	4.50	4.80	4.61	7.40
$Ca_3(PO_4)_2$	None	2.77	2.58	2.77	None
Vol.& Org.	23.30	16.01	13.90	15.77	20.25
Moisture	2.03	1.82	2.30	2.15	2.45
Undet.	1.02	0.86	1.34	1.42	0.64

STUDY No. 3

TABLE 2
Analyses of deposits on immersion heater surfaces at end of experiment.

of this study and were checked frequently. These ratios served as an index of the instantaneous dissloved solids content of each system. A rapid determination of chloride content enabled the operator to calculate the amount of dissolved solids present. Upon closely approaching or meeting the upper limits of solids concentration, a definite amount of system water was dejected and an equivalent amount of make-up added. In this manner, solids concentrations were controlled within a reasonable range. In addition to a daily determination of dissolved and total solids, the pH and alkalinity of each system water were determined.

Each Scale Analyzed

At the completion of operations for this study, the immersion heaters were removed with the utmost care preventing any disturbance or loss of scale deposited upon the heater surfaces. After a miscroscopic and photographic study of each scale deposit was made, the scales were analyzed completely for their chemical contents. In addition, the water from each tower was given a complete analysis. Analyses of the scales are shown in Table 2 and of the waters in Table 1. Photographs of the six immersion heaters upon completion of this study are shown in Figure 5 and show clearly the type and extent of scale formation.

A crystalline reddish-brown scale approximately 1/16 inch thick was deposited on the heating surface of Tower No. 1 containing no treatment. Deposits on heating surfaces of Towers Nos. 2 and 4 containing tetra phospho glucosate were light brown crystalline deposits approximately 1/32 inch thick. The deposits were cup or bubble shaped. The deposit on heating surface of Tower No. 3 containing hexa meta phosphate was light brown, crystalline and cup or bubble shaped. It varied from 1/32 to 1/16 inch in thickness. A reddish-brown non-crystalline deposit of extremely small clusters was formed on the heating surface of Tower No. 5 containing beta glucoside. This deposit exhibited no mechanical adherence. A yellowish-brown non-crystalline deposit of approximately 1/64 inch thick was formed on the heating surface of Tower No. 6 containing quachrom glucosate.

Operating characteristics of each cooling system are shown graphically in Figures 6, 7, 8, 9 and 10. The close relationship of chloride concentrations with total and dissolved solids concentrations indicates clearly the value of the dissolved solids/chloride ratio in controlling solids concentration. Volume percentages of make-up water added and water dejected, or blow down, are plotted for each tower and day of operation. A number of factors account for the variation in the amounts of water evaporated and make-up required from day to day, reflecting atmospheric conditions of temperature and humidity. The pH curve indicates a gradual rise after the second day of operation. As stated previously, all variables other than the two, (1) chemical treatment, and (2) solids concentration were maintained equally for all systems. Tower No. 3 containing hexa meta phosphate exhibited a rise in pH and, therefore, it was necessary to add small amounts of caustic to the other systems from time to time to equalize the pH values. The tendency of the system water containing hexa meta phosphate toward higher pH values indicates a greater degree of hydrolysis and a greater tendency toward scale formation. Table No. 2 listing the scale analyses indicates that phosphate treatment, as hexa meta phosphate and as the organic phosphate, were precipitated in the form of $Ca_3(PO_4)_2$.

Precipitation of Sulfates

That the percentage of $CaSO_4$ in the deposits is appreciable proves that precipitation of sulfates in cooling systems does occur. Table 1 indicates a content of 40 p.p.m. silica in the final water from Tower No. 5 containing beta glucoside. This concentration is greater than shown by the other systems reflecting the well known fact beta glucoside keeps silica in suspension. This is indicated further by Table 2

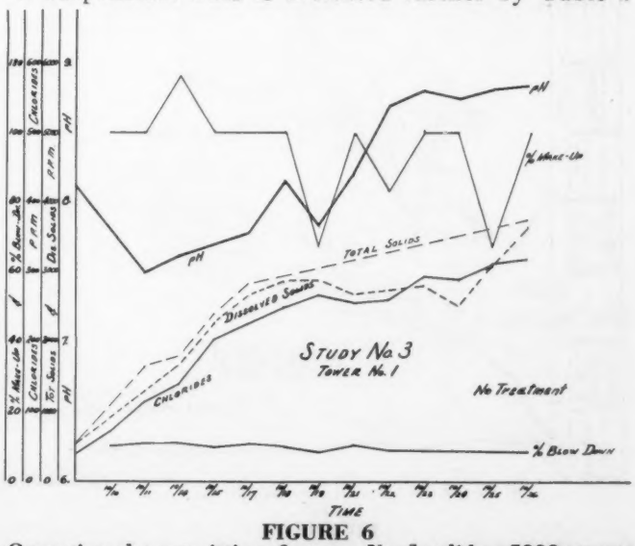

FIGURE 6
Operating characteristics of system No. 1 solids—5000 p.p.m. No treatment.

indicating the percentage of silica in the scale as the lowest for Tower No. 5.

This report on our cooling systems may be considered as preliminary to a series of pure research studies which will isolate the individual ions and elements and determine the critical limits responsible for scale and corrosion troubles in this type of system. In addition, the relative effectiveness of various chemicals in the control of these factors, plus the control of bacterial and algal factors will be studied.

The solution of the water problems in atmospheric cooling systems is often a serious problem involving a careful study of numerous factors. The first step toward a solution is the proper and correct analysis of the problem at hand. Scale, corrosion and living organisms are separate and distinct problems, all requiring separate treatment. With any given condition, it is less costly to treat for any one of these factors than for two or three together. There is no panacea which will take care of all three factors where all three factors actually exist. Iron present as a precipitated deposit, as a corrosion product, or as a result of an iron bacterial infection represents three distinct problems requiring three separate approaches. Too often, this simple fact of properly determining the problem before attempting correction is ignored with disastrous results.

A number of definite facts have been established to date from our experience with the laboratory cooling systems. We believe the following conclusions drawn from this experience are most important and significant:

(1) It is possible to duplicate plant operating conditions in the laboratory and obtain identical scale and corrosion results obtained in practice.

(2) Dissolved Solids concentrations are an important factor in scale control and determine to a large extent the effectiveness of chemicals employed for treatment.

(3) Sulfate and silica deposits are factors in cooling system operation.

(4) Phosphate chemicals hydrolyze reducing, if not eliminating, the effectiveness of so-called threshold treatment.

(5) This type of research is important in isolating factors and concentrations effecting scale and corrosion control in this type of system.

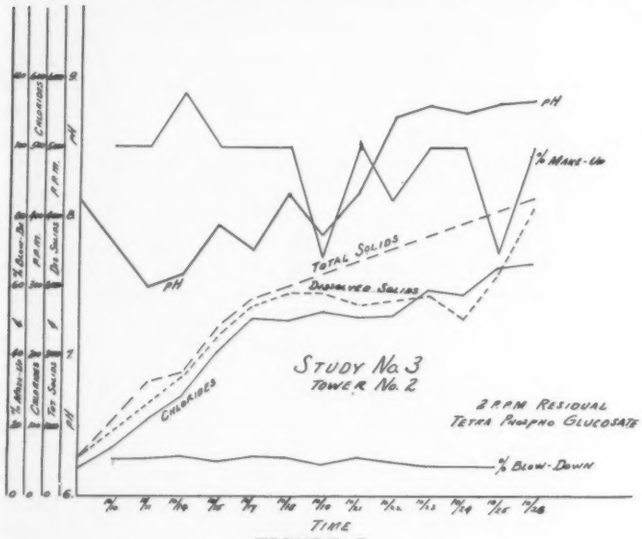

FIGURE 7
Operating characteristics of system No. 2 solids—5000 p.p.m.—tetra phospho glucosate residual.

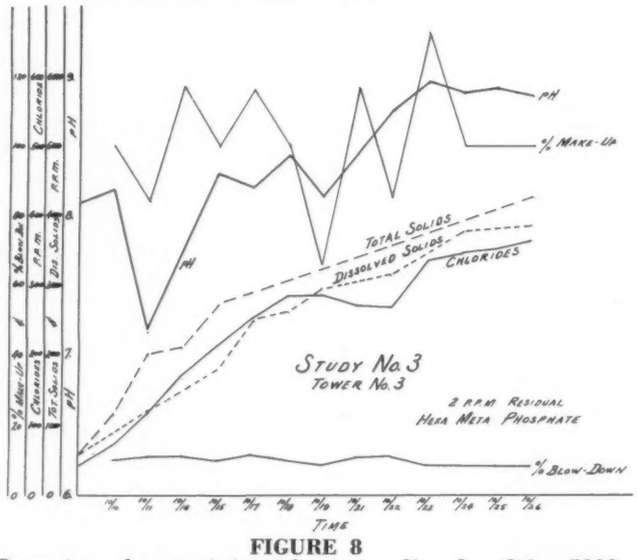

FIGURE 8
Operating characteristics of system No. 3 solids—5000 p.p.m.—hexa meta phosphate residual.

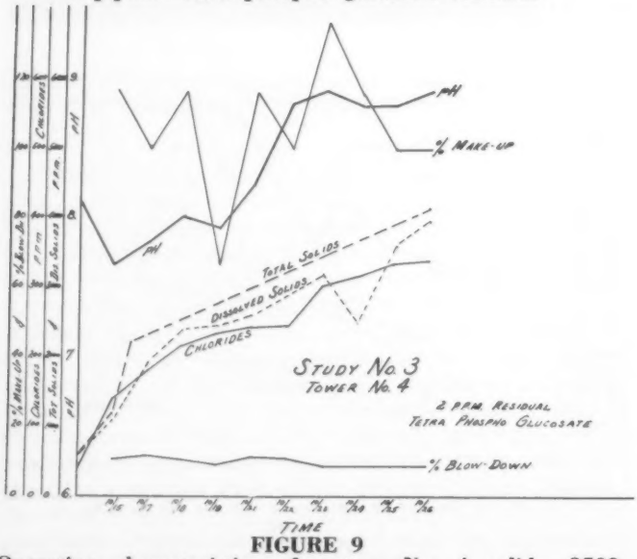

FIGURE 9
Operating characteristics of system No. 4 solids—3500 p.p.m.—tetra phospho glucosate residual.

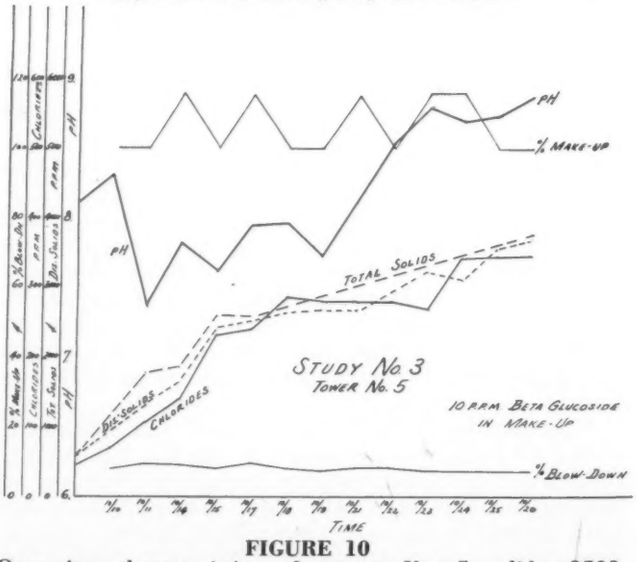

FIGURE 10
Operating characteristics of system No. 5 solids—3500 p.p.m.—beta glucoside 10 p.p.m.

Elements of Vaporization and Condensation

Part XII

Application of the Kremser Method to the Design of Oil Absorbers

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THE conventional oil absorber is a vertical bubble-plate tower in which the gasoline constituents are extracted from the gas stream by a descending counter-current flow of oil. Although the combination of trays, caps and downspouts has come into high favor, recent improvements in packing rings indicates that this form of baffling will regain at least part of its former standing as a means of bringing about intimate contact between gas and its absorbing medium. Perforated plates[2,3] hold some promise because of the low initial cost of such towers, provided a higher flexibility can be obtained in handling gas and oil loads.

The Bubble Plate Tower

The two principal factors to be considered in the design of the bubble plate tower are:

1. Provision of ample flow capacity for the oil and gas streams so as to prevent liquid hold up and entrainment.[1,5,6,7]

2. A fairly close approach toward equilibrium between the gas and oil on each bubble plate.

To take care of factor No. 1 calls for:

a. Adequate down-spouts wherein the entrained vapor can free itself from the oil froth which is formed as the oil flows across the bubble caps.

b. Liquid seals at the base of the down-spout to prevent the flow of gas upward through the down-spout.

c. A tray spacing of 20 inches or more, generally 24 inches, between successive plates, in order to reduce entrainment or the mechanical carrying of liquid droplets upward from plate to plate.[1,5,7]

Factor No. 2 requires the following considerations:

a. Placement of bubble-caps in staggered rows so as to reduce the tendency for the oil to channel across the plate.

b. Proper height for the overflow weir in order to give the rising gas stream a sufficiently deep body of oil to penetrate on each plate.

c. Ample velocity through the slots to provide intimate contact between the gas and oil, however, the velocity must not be so high as to cause the

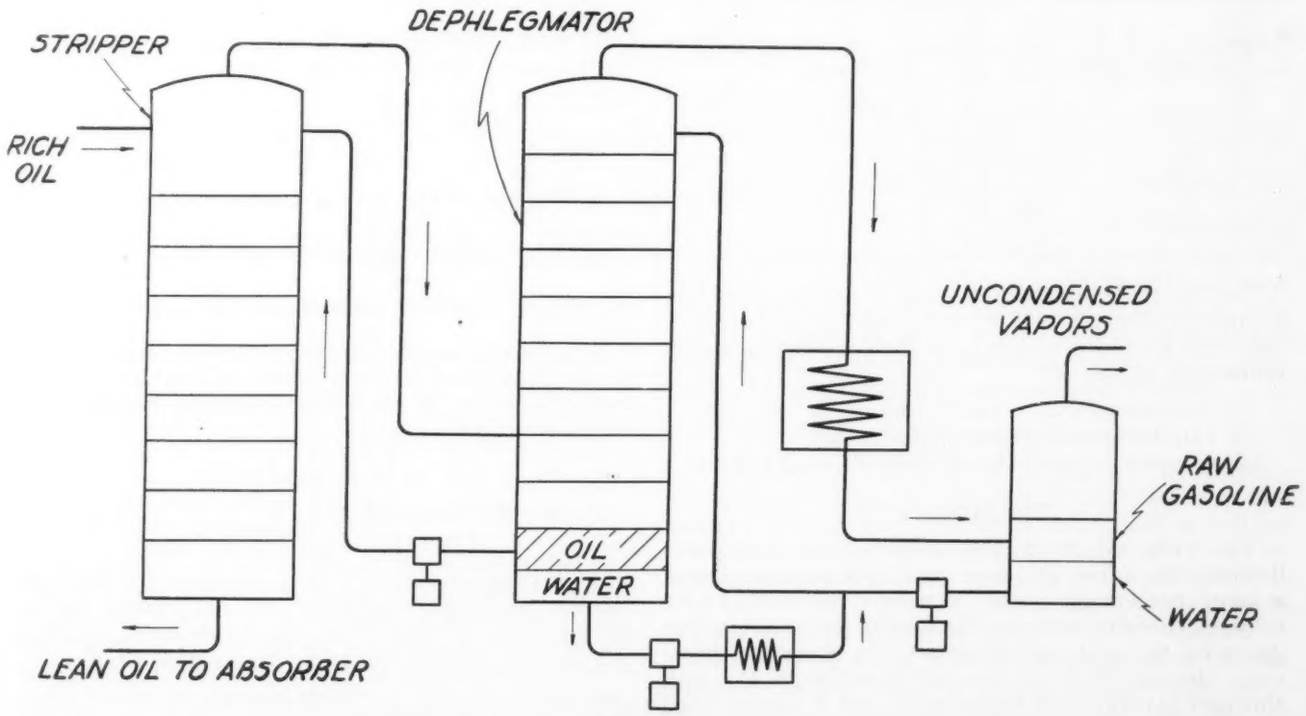

FIGURE 1
Conventional oil absorption and distillation unit.

friction loss in feet of fluid to approach the equivalent head of oil and froth in the down-spout.

An Absorber-Stripper Design Problem

The Kremser[4] absorption factor chart (Figure 3) (as revised by Souders & Brown) can also be used in the design of a stripper or still where the natural gasoline is removed from the absorption oil with steam. This chart is based on an algebraic derivation in which a material balance is made around "n" equilibrium plates. A number of simplifying assumptions are made among which are:

1. The volume of residue gas is substantially the same as the raw gas volume.
2. The ratio of L/V or mols of lean to mols of lean gas is a constant for the absorber as well as the ratio of V/L mols of steam to mols of lean oil for the stripper.
3. The liquid volumes are additive.

The Absorber

An absorber containing 24 actual plates of 66-2/3 percent efficiency is to process a rich gas from some flowing wells. Ninety-five percent of the normal pentane in the raw gas is to be absorbed. The absorption oil has a specific gravity of 0.8 and a molecular weight of 180. Temperature of absorber = 90° F. Gage pr. = 40 lb. Altitude above sea level = 3000 feet. Analysis of the rich gas is as follows:

Component	(% by vol.)
CH_4	= 82
C_2H_6	= 5
C_3H_8	= 3
Iso C_4H_{10}	= 1
N C_4H_{10}	= 3
Iso C_5H_{12}	= 1
N C_5H_{12} +	= 5

The dry oil being fed to the top of the absorber has a vapor pressure at 90° F. of 2.2 millimeters of mercury due to the presence of a little normal pentane remaining in the oil.

1. Calculate the gals. of lean oil/1000 std. cu. ft. dry gas.
2. Calculate the composition of the dry gas.
3. Calculate the gals. of lean oil/1000 std. cu. ft. rich gas.

The Stripper

The rich oil from the absorber is sometimes flashed into a low-pressure vent tank so as to cause a large percentage of the dissolved methane to be released thereby reducing the load of non-condensible gases on the still and condenser. In this case, however, the oil is to be pumped directly to the still through several heat exchangers and a superheated steam preheater to the stripper where the rich oil enters at 375° F. The pressure in the base of the stripper is to be 50 pounds per square inch absolute and the temperature will have fallen to 350° F. due to vaporization of the gasoline constituents. The lean oil is to leave the stripper with the same normal pentane content as the oil which was fed to the absorber. The number of actual plates will be 8, having an efficiency of 62.50 percent or an equivalent of 5 theoretical plates. The problem is to determine the amount of steam required per gallon of rich oil to bring about the desired results.

Solution: I (Absorber)

The absolute pressure in the absorber will be 40 pounds plus atmospheric pressure. At an altitude of 3000 feet above sea level the barometric pressure can be estimated by integrating a perfect gas column of that height as follows:

$$\int Pdv = RT \ln_e P_1/P_2 = \text{ft. of fluid}$$

Where R = 1544/29 for 1 lb. of air
T = Abs. temp. Assume 60° F. or 520° Absolute
P_1 = Pressure at sea level = 14.7 lbs./sq. in.
P_2 = Pressure at 3000 ft. elevation

Substituting into the integrated form:

$$\frac{1544}{29} \times 520 \times \ln_e \frac{14.7}{P_2} = 3000$$

P_2 = 13.05 lbs./sq. in. absolute at 3000 feet elevation

Absorber Calculations
(See definition of terms below)

Comp.	Mol. Frac.	Equilibrium Vaporization K=y/x	Vapor Pressure p	p/π	Absorption Factor $A=\frac{L}{vk}$	$\frac{y_{n+1}-y_1}{y_{n+1}-y_o}$	$\frac{y_{n+1}-y_1}{y_{n+1}}$	Cu. Ft. Absorbed Per 1000 Cu. Ft. of Raw Gas	Cu. Ft. of Residue Gas Per 1000 Cu. Ft. of Raw Gas
CH_4	.82	70	7800	143.5	0.00413	0.00413	0.00413	3.40	816.60
C_2H_6	.05	10	735	13.93	0.0289	0.0289	0.00289	1.45	48.55
C_3H_8	.03	2.7	168	3.17	0.1070	0.1070	0.1070	3.21	26.79
I C_4H_{10}	.01	1.15	67	1.26	0.2515	0.2515	0.2515	2.51	7.49
N C_4H_{10}	.03	0.86	46	0.87	0.3360	0.3360	0.3360	10.10	19.90
I C_5H_{12}	.01	0.36	17	0.32	0.8030	0.8030	0.8030	8.03	1.97
N C_5H_{12} +	.05	0.27	13	0.245	1.070	0.965	0.95	47.50	2.50
Total								72.20	923.80

Total Pressure (π) = 53 lbs./sq. in. abs.
Theoretical plates = 24 × 2/3 = 16

$$px_{c5} = \frac{2.2}{760/14.7} = \frac{2.2}{51.7}$$

$$\pi Y_o = px_{c5} \qquad Y_o = \frac{2.2}{51.7(53)} = .0008$$

Evaluation of theoretical fraction to be absorbed:

$$\frac{y_{n+1} - y_1}{y_{n+1} - y_o} = \frac{.05 - .0025}{.05 - .0008} = 0.965 \text{ for N } C_5H_{12+}$$

$$\frac{y_{n+1} - y_1}{y_{n+1}} = 0.95 \text{ (Actual fraction of N } C_5 \text{ to be absorbed)}$$

By referring to the absorption factor chart (Figure 3) the theoretical fraction (0.965) is read across horizontally to the 16 plate line and then downward to the absorption factor

$$\left(A = \frac{L}{VK}\right) = 1.07$$

From this relationship,

$$L/V = KA = 0.25 \times 1.07 = .289$$

This relationship L/V is a constant for this particular condition, therefore the absorption factors for the other hydrocarbons can be obtained by dividing L/V = .289 by the respective values of K.

$$L/V = \frac{\text{mols lean oil}}{\text{mols of dry gas}}$$

This relationship is not used by plant operators

therefore it must be converted over into gallons of lean oil per thousand standard cubic feet of dry gas.

$$\frac{\left(\frac{.289 \text{ mols} \times 180 \text{ (lbs./mol.)}}{0.8 \times 8.33 \text{ lbs./gal.}}\right)}{380 \text{ (std. cu. ft./lb. mol.)}} = 8.25 \text{ gals./380 std. cu. ft. of gas}$$

$$\text{or } \frac{1000}{380} \times 8.25 \text{ gals.} = \frac{21.7 \text{ gals. of lean oil}}{1000 \text{ std. cu. ft. of dry gas}}$$

The gallons of lean oil per thousand standard cubic feet of rich gas will be smaller than the ratio of lean oil to lean gas by the ratio of the lean gas volume to that of the rich gas. This ratio will therefore be

$$21.7 \times .9238 = \frac{20.02 \text{ gals. lean oil}}{1000 \text{ std. cu. ft. rich gas}}$$

The Stripper

The still is a bubble-plate tower (Figure 1) consisting of two sections. The upper half is the dephlegmator and the lower, the stripping section. The function of the dephlegmator is that of knocking back the absorption oil which is vaporized in the stripping section, through the refluxing of raw gasoline over the top of the tower. The stripper reverses the operation of the absorber in that it drives out the gasoline and other lighter hydrocarbons which are recovered in the absorber from the raw gas. Live steam generally is used as a stripping agent as it reduces the partial pressure of the hydrocarbons in the lower part of the still: furthermore the steam condenses readily in the upper portion of the dephlegmator and also in the condenser thereby bringing the partial pressure of the hydrocarbons back to a higher level for ready condensation.

0.779 mols of lean oil. For every .405 mols of steam there would be 0.221/.779 mols of dissolved gases or 0.283. The volume or mol fraction of the vapor space at the base of the dephlegmator which would be occupied by steam, would be .405/(.405 + .283) = .588. From the standpoint of vaporization, the rich oil would flash off its vapors to the same extent provided no steam were used but the total pressure on the still would have to be lowered to 50—29.4 = 20.6 lbs./sq. in. absolute. Effective condensation of the raw gasoline vapors could not be obtained at such a low total pressure, by means of atmospheric cooling water.

About 20 years ago, a few natural-gasoline-plant operators considered the use of some stripping agents other than steam for denuding absorption oil. It was thought that dry residue gas might be as effective as steam and that it could be obtained at a much lower price. The folly of such an idea was soon shown up when it was found that the overhead vapors were non-condensible and that the gas had been brought back to substantially the same composition as it was when it had first flowed into the absorber.

A combination stripper and dephlegmator operating in series is shown in Figure 2. Some companies claim that more economical operation can be obtained by refluxing water over the dephlegmator thereby creating an internal gasoline reflux.

Variations in Absorber Operations

With changing markets and variations in price schedules for different products, the natural gasoline manufacturer must keep in step by increasing the efficiency of the absorption system when prices are high. This result can be accomplished either by lowering the temperature of the absorption oil and raw gas or by raising the pressure on the tower, e.i., within the pressure range from atmospheric up to the inversion point of the retrograde region. Above this point the opposite effects may be experienced.

Stripper Calculations

	Mols.	Rich Oil Mol. Frac.	Stripping Factor $S=\frac{VK}{L}$	Ratio of Mols. Steam / Mols. Lean Oil	K 350° F. 50	Actual Frac. Stripped $\left(\frac{x_e - x_n}{x_n}\right)$	This Frac. $\left(\frac{x_e - x_n}{x_e - x_o}\right)$	Mols. Stripped Out
CH_4	.004	.0116	243.00	0.405	600	1.00	1.00	.004
C_2H_6	.0009	.0026	10.12	0.405	25	1.00	1.00	.0009
C_3H_8	.0032	.0093	5.06	0.405	13	1.00	1.00	.0032
I C_4H_{10}	.0025	.0073	3.24	0.405	8	1.00	1.00	.0025
N C_4H_{10}	.0101	.0294	2.83	0.405	7	1.00	1.00	.0101
I C_5H_{12}	.0080	.0234	2.03	0.405	5	.982	.982	.0078
N C_5H_{12}	.0474	.1380	1.86	0.405	4.6	.976	.976	.0462
Lean Oil	.2670	.7790	.31	0.405	0.76	.31	.31	.0828

$$x_n = \frac{2.2}{13.1 \times 51.7} = .00325 \text{ (mol. fraction of N pentane in lean oil)}$$

$$\frac{x_e - x_n}{x_e} = \frac{0.1380 - .00325}{0.1380} = 0.976 \text{ (Actual fraction of N pentane to be stripped out of rich oil)}$$

Stripping factor (S) for 0.976 and 5 theoretical plates = 1.86

$$\frac{V}{L} = \frac{S}{K} = \frac{1.86}{4.6} = 0.405 \text{ mols. of steam/mol. of lean oil}$$

$$\frac{\text{lbs. of steam}}{\text{Gals. Lean Oil.}} = \frac{.405 \times 18}{180} = .2705 = \frac{V}{L}$$

$$(8.33 \times .8)$$

Where 18 = lbs. of water per lb. mol.
180 = lbs. per mol. wt. of oil
$8.33 \times .8$ = wt. of gallon of oil

The partial pressure of the steam in the still varies from substantially 50 pounds in the base of the stripper section to 29.4 pounds at the base of the dephlegmator. The partial pressure is obtained by considering the ratio of steam to hydrocarbon vapors at any point in the tower. From the above calculations it is seen that there are 0.405 mols of steam per mol of lean oil and 0.221 mols of dissolved gases per

Effect of Pressure Changes

A marked reduction of oil circulation can be realized by increasing the pressure in the absorber. For example (See Figure 4) the oil circulation in gallons per 1000 standard cubic feet of residue gas must be increased from 6 gallons up to 65 gallons if the pressure is lowered from 200 pounds down to 20 pounds per square inch absolute. Gasoline plants operate as a rule with 40 to 50 pounds gage pressure on the absorbers unless there is a demand for high pressure such as a remote market for the dry gas as fuel or for lifting of oil wells in the field. In other

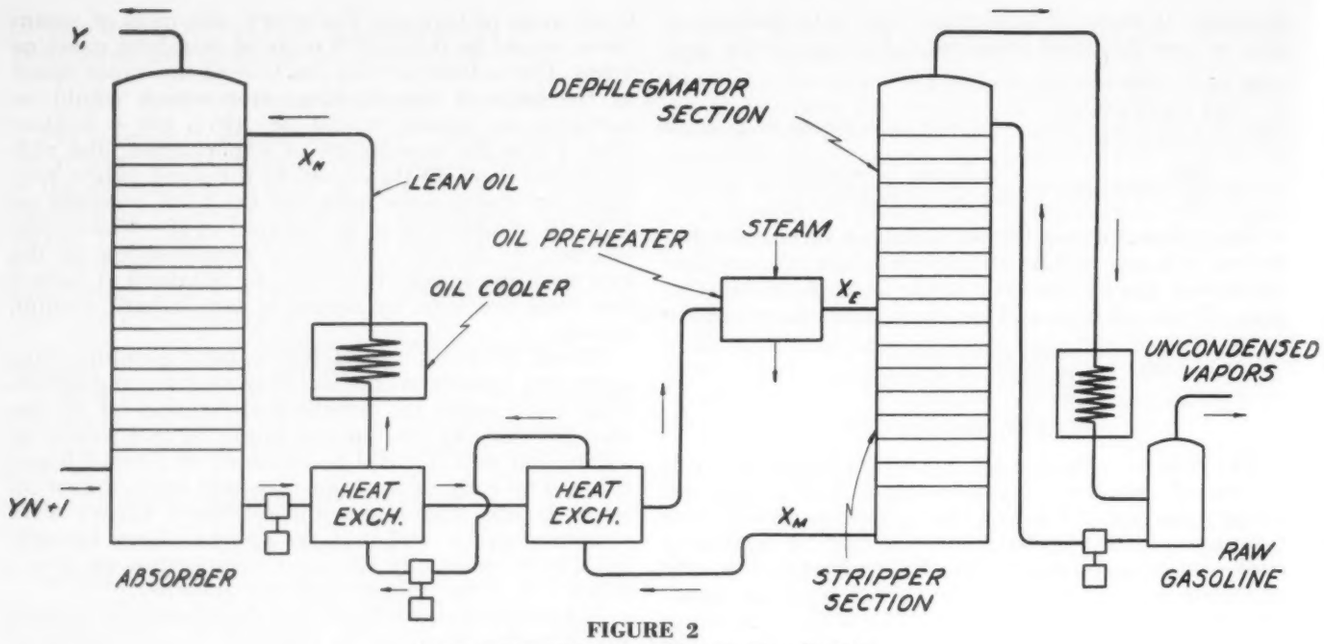

FIGURE 2
A two tower stripper-dephlegmator still unit.

words the additional cost of compressing gas to a high level offsets by far the saving in oil circulation costs such as steam for stripping and for pumping the oil.

The reduction in the temperature of the absorption oil is often the most economical method of increasing the efficiency of an absorber. The oil should be cooled to within 10° F. of the circulating water and the water within 5 to 10° F of the wet-bulb temperature For further refrigeration it is customary to use propane or butane as a means of heat removal[3]. In Figure 5 it is shown that an oil circulation of 12 gallons

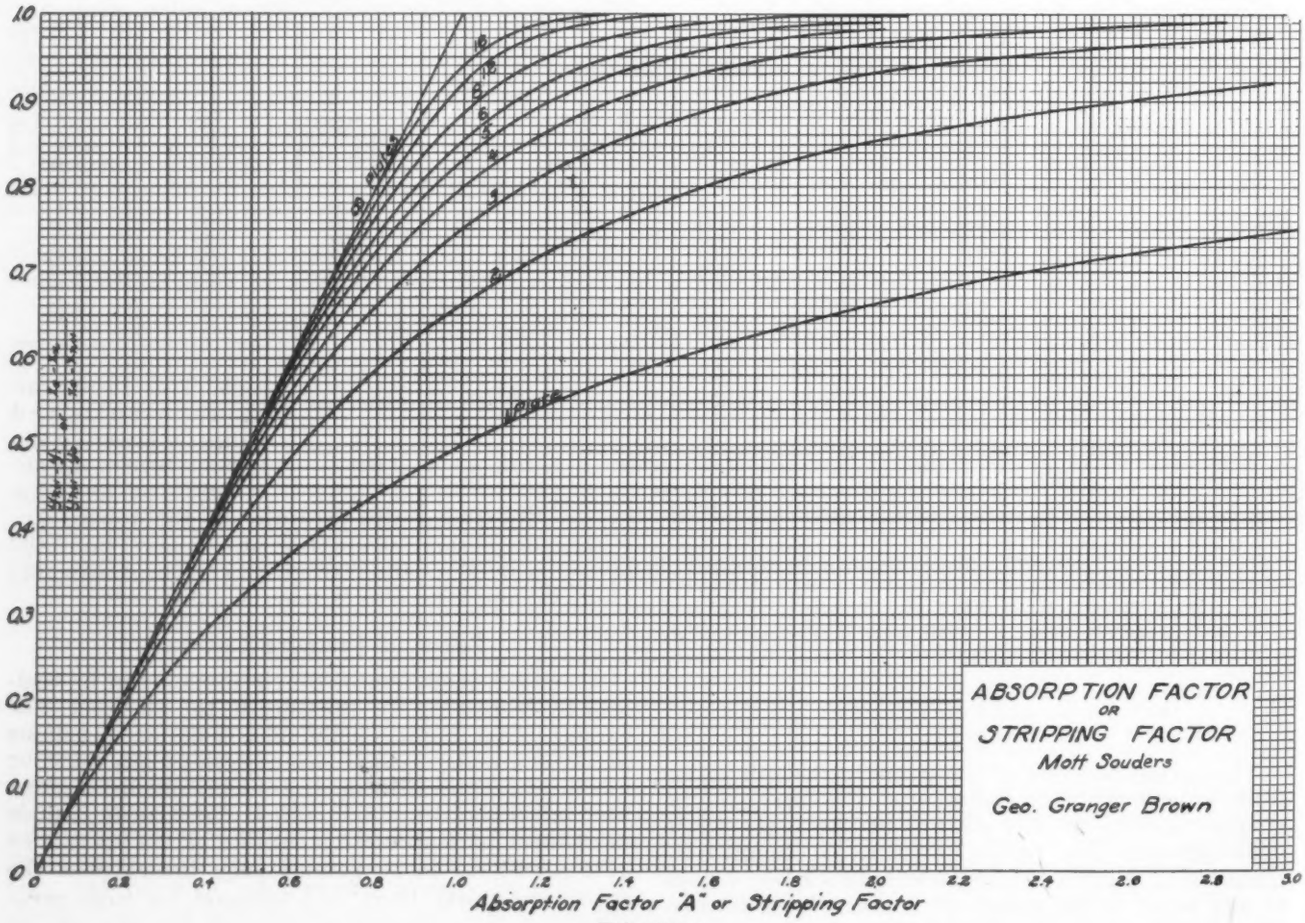

FIGURE 3
Absorption factor chart.

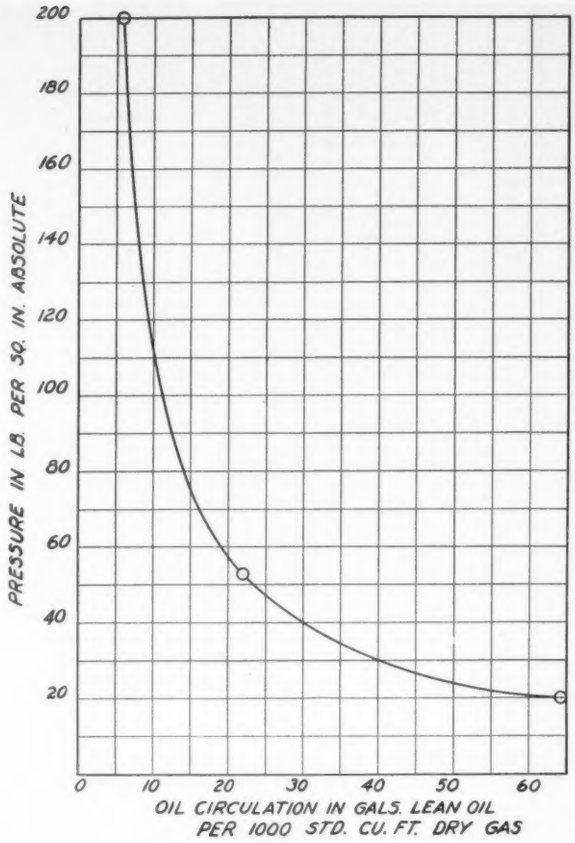

FIGURE 4

Effect of pressure on oil circulation (below retrograde region). Constants—Temp.=90° F. Theo. plates=16.

per thousand cubic feet of lean gas at 60° F. is just as effective as 32 gallons per thousand cubic feet at 110° F.

Number of Theoretical Plates

By increasing the number of bubble plates in the tower, the oil circulation can be materially reduced. For example, in Figure 6A, it is easily seen that whereas 41 gallons of oil per thousand standard cubic feet of dry gas are required for a 4-plate tower, only 22 gallons are needed for a 16-theoretical-plate absorber. The most economical tower to build will, of course, depend upon the relative value of the gasoline to be marketed and the cost of operating the plant. Probably some intermediate point such as 8 to 12 theoretical plates may prove to be the most economical tower to select, however, the trend recently has been toward the installation of more plates in each absorber. This tendency may be due to the increasing demand for propane and the butanes.

Percentage Normal Pentane Recovered

Many absorbers are designed on the basis of the recovery of a certain percentage of normal pentane. As higher percentages of the pentanes are desired more absorption oil must be circulated. This relationship is shown in Figure 6B. The curve brings out the fact that as the last small percentage of normal pentane is recovered from the raw gas, the oil circulation must be increased to a great extent.

Selection of an Absorption Oil

Each natural gasoline situation needs to be studied before a proper selection can be intelligently made

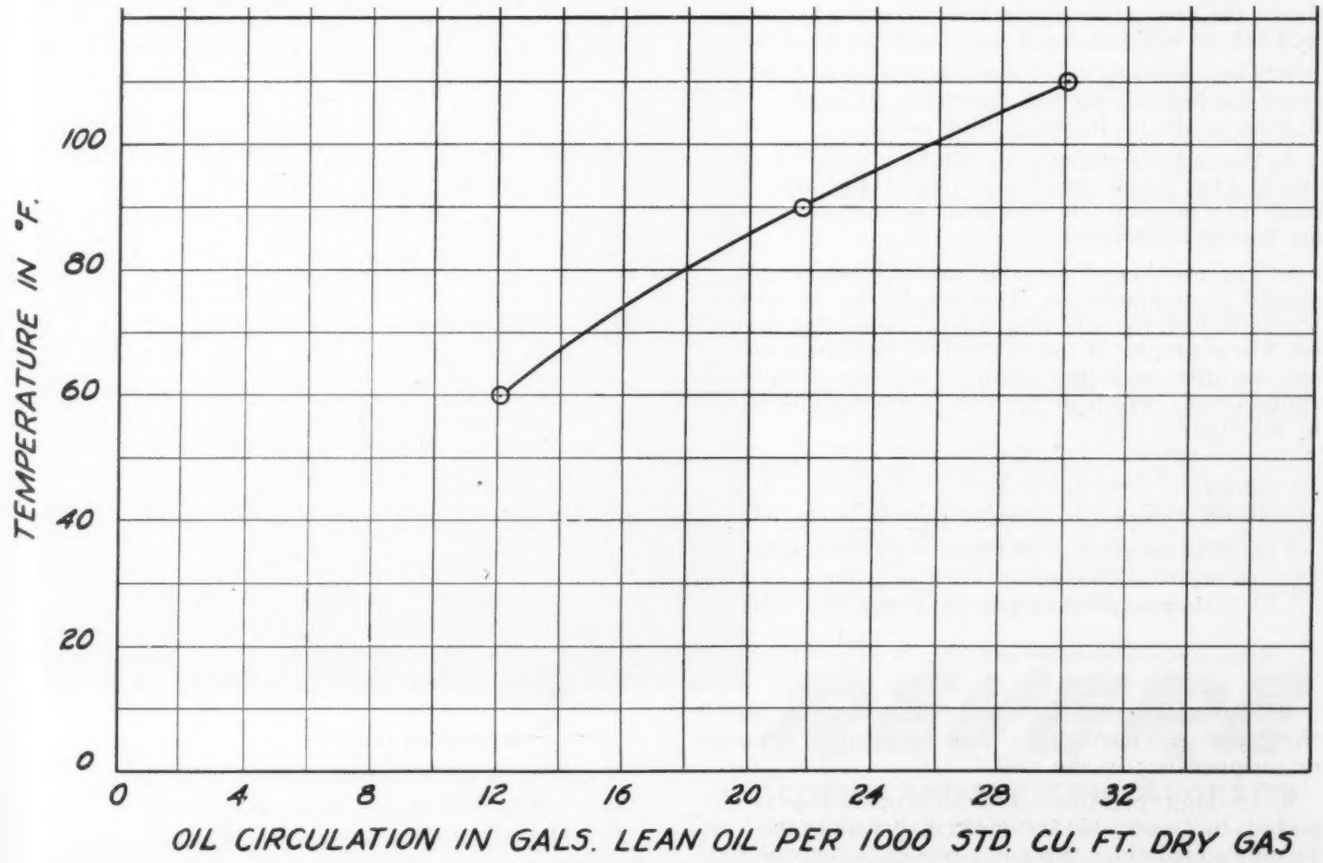

FIGURE 5

Effect of temperature on oil circulation. Constants—Pr.=53 lbs. Theo. Plates=16.

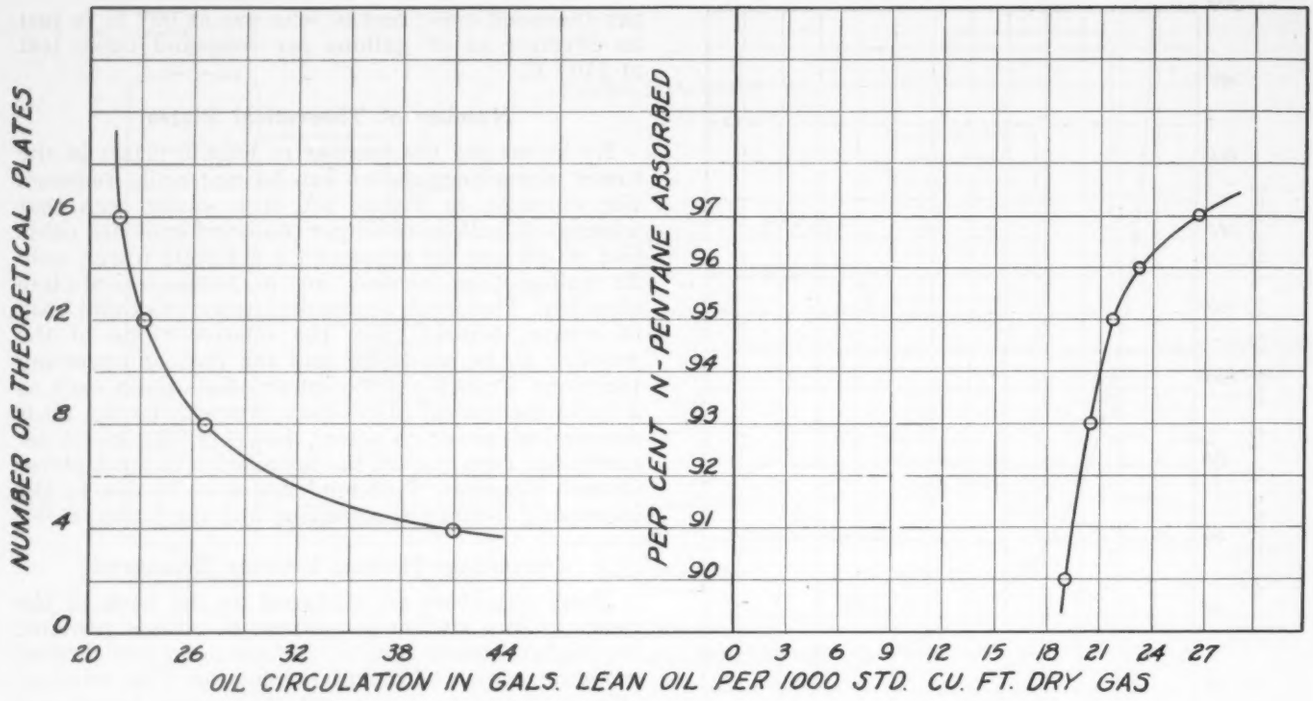

FIGURE 6A

Effect of number of theoretical plates on oil circulation. Constants—Pr.=53 lbs. Temp.=90° F.

FIGURE 6B

Effect of percentage of normal pentane absorbed on oil circulation. Constants—Pr.=53 lbs. Temp.=90° F. Theo. plates=16.

on an absorption oil. There are a few general rules, however, which may be followed.

1. The oil should have an initial boiling point well above the end point of the raw natural gasoline, so that the oil will not distill over with the gasoline.

2. The oil should be free of heavy ends which may cause too high a pour test thereby resulting in solidification of the oil in the cooling coils.

3. Waxy hydrocarbons should be absent (or present in very small amounts). Heavy asphaltic fractions may promote the formation of emulsions which are highly undesirable.

4. The number of mols per unit of liquid volume should be a maximum. This result can be usually accomplished by selecting a low molecular weight oil. For example: If the absorption capacities of two oils are the same per pound molecular weight or (pound mol) which of the two following oils would be selected?

	A.P.I. Gr.	Sp. Gr.	Mol. Wt.
Oil (A)	35	.85	210
Oil (B)	40	.825	180

$$\text{Lb. Mols. per gallon of Oil (A)} = \frac{.85 \times 8.33}{210} = .0336$$

$$\text{Lb. Mols. per gallon of Oil (B)} = \frac{.825 \times 8.33}{180} = .0382$$

$$\text{Relative effectiveness per gallon} \frac{A}{B} = \frac{.0382}{.0336} = 1.135$$

5. The absorption oil should be one from which the gasoline constituents can be readily denuded or stripped out in the still.

6. In high pressure absorbers operating at 600 pounds or more, higher molecular weight oils are recommended since there is a tendency for vaporization to take place in the retrograde region, especially for the lighter oils.

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Nomenclature

A = Absorption Factor $= \frac{L}{VK}$

L = Mols. of lean oil

V = Mols. of dry gas

K = Equilibrium vaporization constant $= Y/X$

Y = Mol. fraction of any component in the vapor

X = Mol. fraction of same component in the liquid

N = Number of plates from the top of the absorber or the top of the stripper

$N+1$ = Theoretical plate below nth plate

Y_{n+1} = Mol. fraction of any component in the raw gas

Y_1 = Mol. fraction of any component in the lean gas

Y_o = Mol. fraction of any component in the lean gas provided equilibrium is attained between lean oil and lean gas

$S = \frac{VK}{L}$ = Stripping factor

V = Mols. of steam (instead of mols. of dry gas)

X_e = Mol. fraction of each component in rich oil

X_n = Mol. fraction of each component in lean oil

X_{n+1} = Mol. fraction of each component in lean oil if equilibrium is attained between oil and stripping medium. (For steam and oil $X_{n+1} = 0$)

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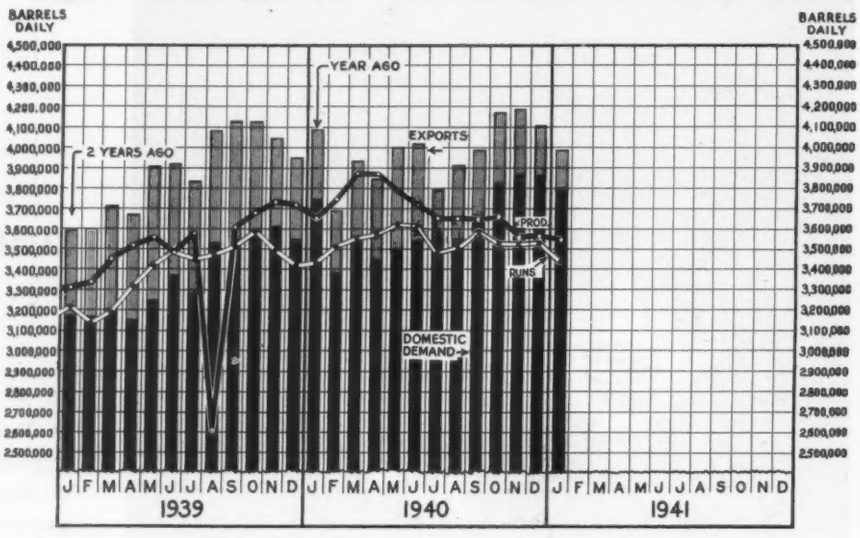
Export-Import Situation Only Market Threat

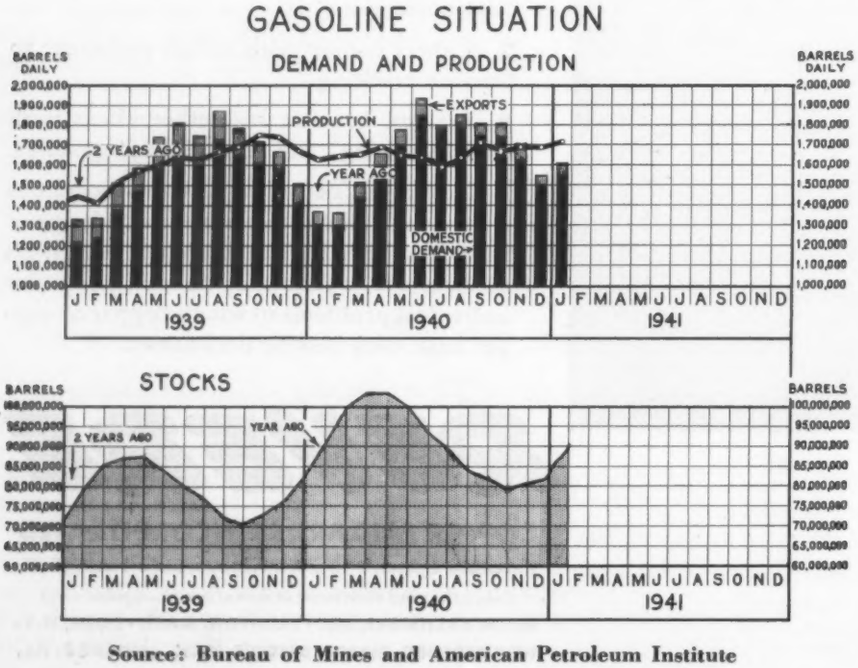
By WILLIAM H. STRANG

FINAL statistics on the export and import of United States crude and refined products during 1940, as compiled by the United States Bureau of Mines, reveal that the tendency toward unfavorable balance, in effect throughout the year, was increased by import of 8,258,000 barrels of crude and refined products in December, against an export volume of 6,991,000 barrels. Blockades affecting our best European customers will presumably be tightened during 1941, the embargo on aviation gasoline is not likely to be lifted during this period, and there are many conceivable shifts in the international political situation which might leave us with Canada as our only customer due to the loss of Russia, Japan and the West Indies.

Reaction of all these factors would reduce United States crude exports to something little more than the 1,000,000-barrel monthly average taken by Canada during 1940. On the more optimistic side, there is a possibility that the reduction in exports to steady customers during the latter months of 1940 was a temporary condition, particularly in Japan and Canada, and that the jump in imports was also a temporary effect of the hemisphere defense and good will programs, linked with pressure of accumulating crude stocks in South America. Undoubtedly some of the November - December import volume was rushed to fill reciprocal trade treaty agreements.



Source: Bureau of Mines, except data for January, 1941, which is estimated



Source: Bureau of Mines and American Petroleum Institute

With due consideration to the importance of foreign markets in the welfare of the American oil industry, it may still be said that the worst combination of circumstances affecting foreign trade will not depress internal conditions to a serious extent. Final figures on the 1940 demand for United States oils, crude and refined, reflect a gain in daily average demand of 2.1 percent, representing an increase of 82,000 barrels daily effected in spite of a 30.9 percent reduction in total exports. Demand for domestic crude increased 7.2 percent, creating a daily market for 243,000 additional barrels. Forecasts of domestic demand for 1941 promise a 5- to 10-percent increase which would take the sting out of the loss of a major portion of the export market for most companies.

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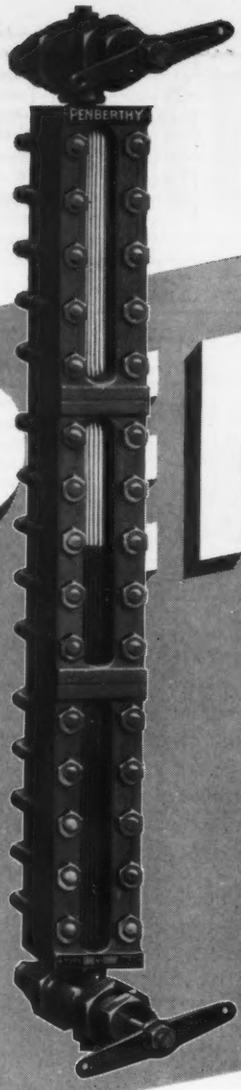

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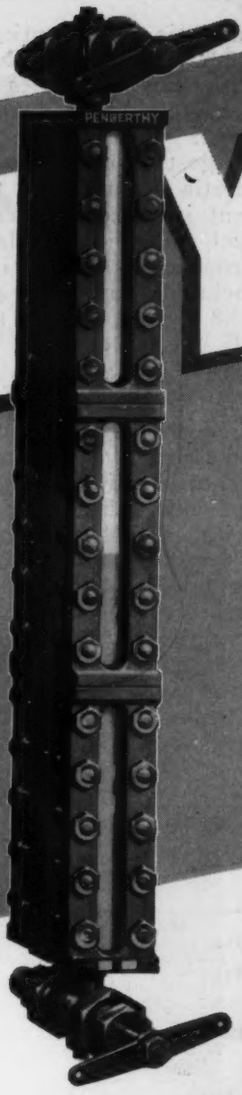

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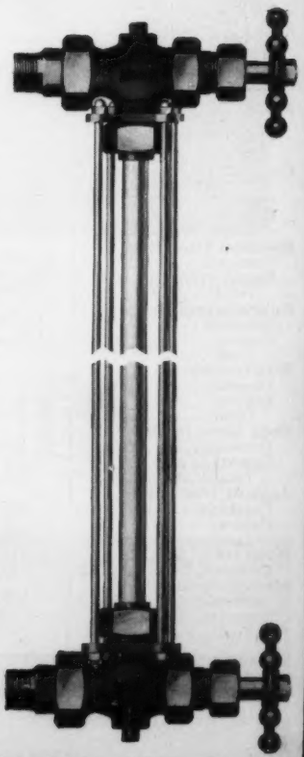

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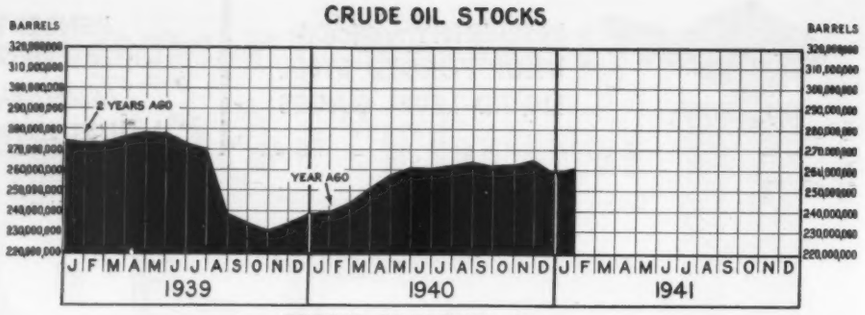
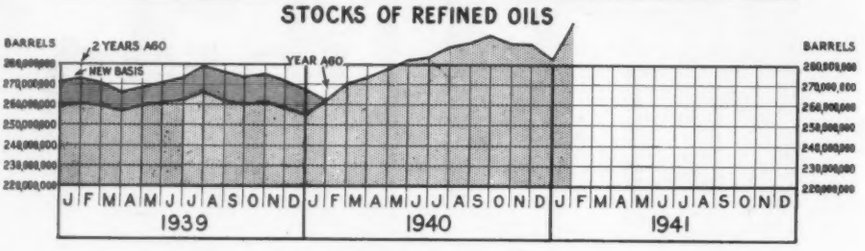
domestic consumption of petroleum products increased in 1940, with the quantities entailed in these increases being generally larger than the export losses. Largest comparative gain in domestic demand was the 18.5 percent increase registered for light fuel oils and distillates. Largest drop in exports was in motor fuel, including aviation gasoline, off 43.8 percent in 1940, and kerosene, off 59.1 percent.

Stocks Above Year Ago

Stocks of crude and refined oil on February 8 were above the inventories of a year ago, residual fuel oils being the only exception with a 2.4 percent difference. Crude oil stocks at 260,250,000 barrels were 8.7 percent above last year's level, which was still reflecting the shutdown in August. Increased demand and a better statistical balance of crude and gasoline stocks render it unlikely that any remedial shutdown will be contemplated in the first part of 1941. Gas oil and distillate fuel stocks were 41.1 percent above the Februarv 10, 1940, level, a condition aggravated in the winter months by the unprecedented demand for residual fuel oils. Gasoline stocks gained 1.8 percent over the inventory of February 10, 1940, another reflection of increased residual fuel oil demand.





Source: Bureau of Mines

Demand for All Oils 2 Percent Higher in 1940

	DECEMBER			YEAR		
	1939	1940	Percent Change	1939	1940	Percent Change
SUMMARY						
Total Demand	123,939,000	127,267,000	+ 2.9	1,420,035,000	1,453,989,000	+ 2.4
Daily Average	3,998,000	4,105,000	+ 2.7	3,891,000	3,973,000	+ 2.1
Exports:						
Crude Petroleum	4,656,000	2,074,000	— 55.5	72,076,000	51,600,000	— 28.4
Refined Products	8,557,000	4,917,000†	— 42.5	116,883,000	78,989,000	— 32.4
Total Exports	13,213,000	6,991,000	— 47.1	188,959,000	130,589,000	— 30.9
Domestic Demand:						
Total Domestic Demand	110,726,000	120,276,000	+ 8.6	1,231,076,000	3,323,400,000	+ 7.5
Daily Average	3,572,000	3,880,000	+ 8.6	3,373,000	3,616,000	+ 7.2
TOTAL DEMAND FOR PRODUCTS						
Motor Fuel:						
Domestic	43,807,000	46,413,000	+ 5.9	555,509,000	589,424,000	+ 6.1
Exports	3,136,000	1,983,000	— 36.8	44,638,000	25,107,000	— 43.8
Total	46,943,000	48,396,000	+ 3.1	600,147,000	614,531,000	+ 2.4
Aviation Gasoline: (included above):						
Domestic	292,000	494,000	+ 69.2	*	5,368,000	.....
Exports	372,000	497,000‡	+ 33.6	4,234,000	4,295,000	+ 1.4
Total	664,000	991,000	+ 49.2	.....	9,663,000	.....
Kerosene:						
Domestic	6,613,000	7,808,000	+ 18.1	60,503,000	68,776,000	+ 13.7
Exports	652,000	116,000	— 82.2	8,241,000	3,374,000	— 59.1
Total	7,265,000	7,924,000	+ 9.1	68,744,000	72,150,000	+ 5.0
Gas Oil and Distillate Fuels:						
Domestic	17,168,000	19,992,000	+ 16.4	138,723,000	164,448,000	+ 18.5
Exports	1,998,000	953,000	— 52.3	32,020,000	19,172,000	— 40.1
Total	19,166,000	20,945,000	+ 9.3	170,743,000	183,620,000	+ 7.5
Residual Fuel Oils:						
Domestic	31,262,000	33,665,000	+ 7.7	319,738,000	335,655,000	+ 5.0
Exports	1,320,000	913,000	— 30.8	17,485,000	16,077,000	— 8.1
Total	32,582,000	34,578,000	+ 6.1	337,223,000	351,732,000	+ 4.3
Lubricants:						
Domestic	1,825,000	1,875,000	+ 2.7	23,713,000	24,657,000	+ 4.0
Exports	1,310,000	588,000	— 55.1	11,881,000	10,494,000	— 11.7
Total	3,135,000	2,463,000	— 21.4	35,594,000	35,151,000	— 1.2
Wax (pounds):						
Domestic	43,971,000	31,538,000	— 28.3	325,461,000	356,653,000	+ 9.6
Exports	14,603,000	8,778,000	— 39.9	232,664,000	190,065,000	— 18.1
Total	58,574,000	40,316,000	— 31.2	558,125,000	546,718,000	— 2.1
Coke (short tons):						
Domestic	123,600	140,500	+ 13.7	1,421,700	1,403,500	— 1.3
Exports	12,600	25,700	+ 51.0	286,200	302,100	+ 5.3
Total	136,200	166,200	+ 22.0	1,707,900	1,705,600	— 0.1
Asphalt (short tons):						
Domestic	257,000	238,700	— 7.1	4,926,100	5,123,600	+ 4.0
Exports	2,200	28,700	+ 92.3	42,400	296,800	+600.0
Total	259,200	267,400	+ 3.1	4,968,500	5,420,400	+ 9.1
Road Oil:						
Domestic	71,000	169,000	+138.0	7,846,000	7,847,000	+ .01
Miscellaneous:						
Domestic	206,000	219,000	+ 6.3	2,223,000	2,175,000	— 2.2
Exports	14,000	47,000	+235.7	123,000	944,000	+667.5
Total	220,000	266,000	+ 17.3	2,346,000	3,119,000	+ 32.9

* Not available. † Exclusive of 12,000 barrels exported from non-contiguous territories but inclusive of 457,000 barrels shipped from U. S. to territories. ‡ Includes 77,000 barrels anti-knock compounds.

In the latest projection of current trends issued by the United States Bureau of Mines, these statements occur: "The domestic demand for motor fuel in February is estimated as 39,000,000 barrels, the daily average of which is 7.6 percent higher than the actual demand in February, 1940. The estimate of exports for motor fuel, based upon forecasts by the principal exporters, is 1,800,000 barrels compared to an actual export of 1,900,000 barrels in February, 1940. The bureau is estimating an increase in finished gasoline stocks of 5,800,000 barrels, which is 2,000,000 barrels less than the increase in Februarv, 1940, when the heavy demand for heating oils entailed large runs to stills."

Previously the bureau had estimated a peak of 96,000,000 barrels in gasoline stocks at March 1, 1941, as compared with almost 104,000,000 barrels at that time in 1940. This anticipation followed from a prediction of an inventory of 82,000,000 barrels on December 31, 1940, a level actually exceeded by 1,400,000 barrels. Unless the 90,864,000-barrel inventory of February 1 is subjected to another drastic increase, such as that which it incurred in the first week of February, when stocks leaped 2,401,000 barrels, the 96,000,000-barrel approximation for March 1, 1941, should stand. That stock position would be a material improvement because of the expected increase

for this refinery!

Five Elliott deaerating feedwater heaters are in use by a well-known oil refinery in connection with a very modern special process. The heaters take Zeolite water, heat it to saturated steam temperature, deaerate it to an oxygen content of zero for use in waste-heat boilers.

The design and performance of the first unit, installed three years ago, was so satisfactory that four more just like it have been ordered.

For outdoor location, the units were made tall, with water storage space underneath the deaerating heater proper, and an extended shell section used for support.

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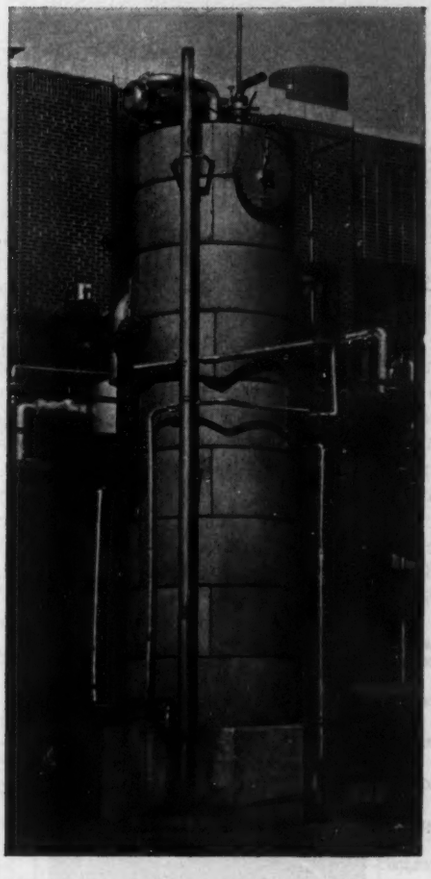
●

All of which comes down to the point that if you want top-flight heater design and performance, Elliott can provide it. We have illustrated bulletins that help to prove it—sent at your request.



Installation view of one of the five heaters, showing typical outdoor location and lagging.

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in domestic motor fuel consumption, and also because the figure would include an increase of several million barrels in essential aviation gasoline stocks.

Tanker Rates Down

Chartering rates on oil tankers have decreased substantially in the past few months, and are not expected to regain their December level during the rest of the winter, according to the United States Maritime Commission. The commission noted an announcement of December 19, that there was adequate tanker tonnage available for the needs of this country, had been borne out, and that sufficient tonnage would be available for the rest of the winter. Specific commission recommendations to oil companies were (1) utilization of heating and fuel oil stocks in a measure greater than normal; (2) elimination, to the greatest possible extent, of long hauls and the employment of vessels eligible for coastwise trade in foreign service, and (3) avoidance of unnecessarily large stocks, particularly of gasoline.

Improvement in tanker rates on various products from Gulf ports to points east of Hatteras has been marked. Rates for December, 1940, January 4, 1941, January 21, 1941, and February 15, 1941, were as follows: Gasoline, 70, 55, 55 and 36 cents; kerosene, 75, 58 and 57 cents; heavy crude, 66, 66, 66 and 56 cents; light crude, 59, 59, 59 and 46 cents.

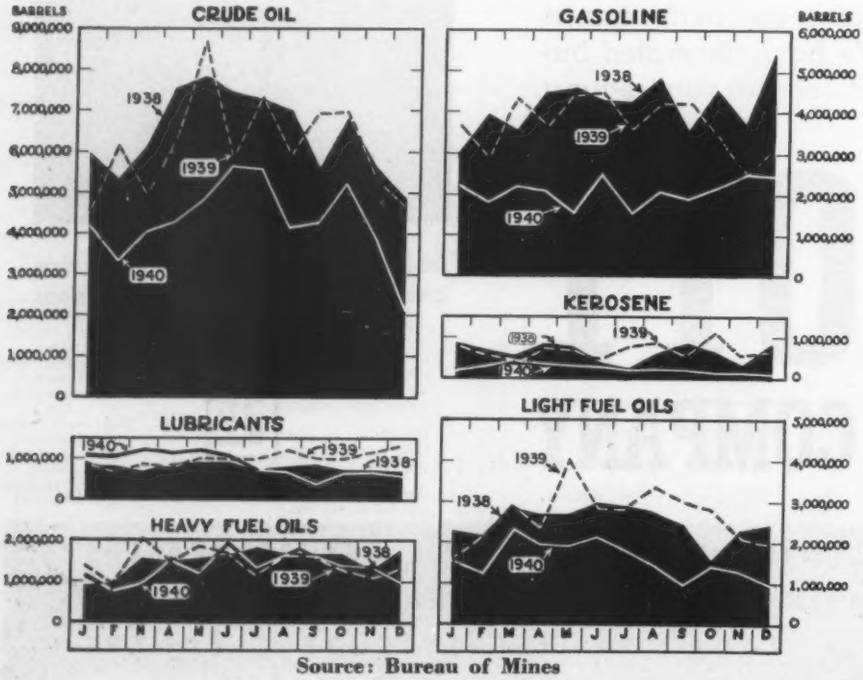
Summary of Bureau of Mines Forecasts for February, 1941
(Barrels)

	Forecast February, 1941	Forecast January, 1941	Actual February, 1940	Percent Change for February, 1940–1941
Demand for Motor Fuel*:				
Domestic demand	39,000,000	43,000,000	37,557,000	+ 3.8
Exports	1,800,000	1,900,000	1,903,000	— 5.7
	40,800,000	44,900,000	39,460,000	+ 3.3
Supply of Motor Fuel:				
Straight-run and cracked gasoline production	42,200,000	46,180,000	43,186,000	— 2.3
Natural gasoline used at refineries	3,100,000	3,520,000	3,067,000	+ 1.1
Total refinery production	45,300,000	49,700,000	46,253,000	— 2.1
Benzol and other natural gasoline	1,300,000	1,500,000	1,062,000	+18.3
Imports	.....	.....	3,000	.....
Increase in finished stocks	5,800,000	6,300,000	7,858,000	—35.5
Available supply	40,800,000	44,900,000	39,460,000	+ 3.3
Crude Oil Requirements:				
Percent yield of gasoline from crude	42.49	42.59	42.44	+ 0.1
Refinery crude required	99,310,000	108,420,000	101,766,000	— 2.5
Daily average	3,546,800	3,497,400	3,509,200	+ 1.1
Foreign crude runs	3,500,000	3,700,000	2,166,000	—38.1
Exports	3,500,000	3,900,000	3,327,000	— 4.9
Fuel and losses	2,300,000	2,700,000	1,172,000	—49.0
Total demand for domestic crude	101,610,000	111,320,000	104,099,000	— 2.4
Daily average	3,628,900	3,591,000	3,589,600	+10.8
Increase in domestic stocks	.....	.....	4,569,000	.....
Actual production	.....	.....	108,668,000	.....
Daily average	.....	.....	3,747,200	.....

* The term "Motor Fuel" as used in this report includes gasoline, naphtha, and benzol used for all purposes, but does not include heavier distillates used in the operation of tractors or burned in Diesel engines.

The United States Bureau of Customs preliminary figures on imports of crude oil and fuel oil within quota limitations provided under trade agreements, covering January, 1941, show that Venezuela sent 132,232,000 gallons on a yearly quota of 1,913,049,600 gallons; Netherlands, 62,112,457 gallons on a 578,806,200-gallon quota; Colombia 6,581,305 gallons on an 86,956,800-gallon quota, and other countries, mostly Mexico, 46,160,567 gallons on a 138,587,400-gallon quota.

Imports for 1940 showed tremendous gains over those of 1939. Crude oil imports for 1939 totalled 28,477,000 barrels, increasing 46 percent to 41,525,000 barrels. Re-



Source: Bureau of Mines

Changes from Year Ago in Stocks of Crude and Refined Oils in the United States

(Figures indicate barrels)

LATEST WEEKLY DATA

(Sources: Crude stocks, Bureau of Mines; all other figures American Petroleum Institute.)

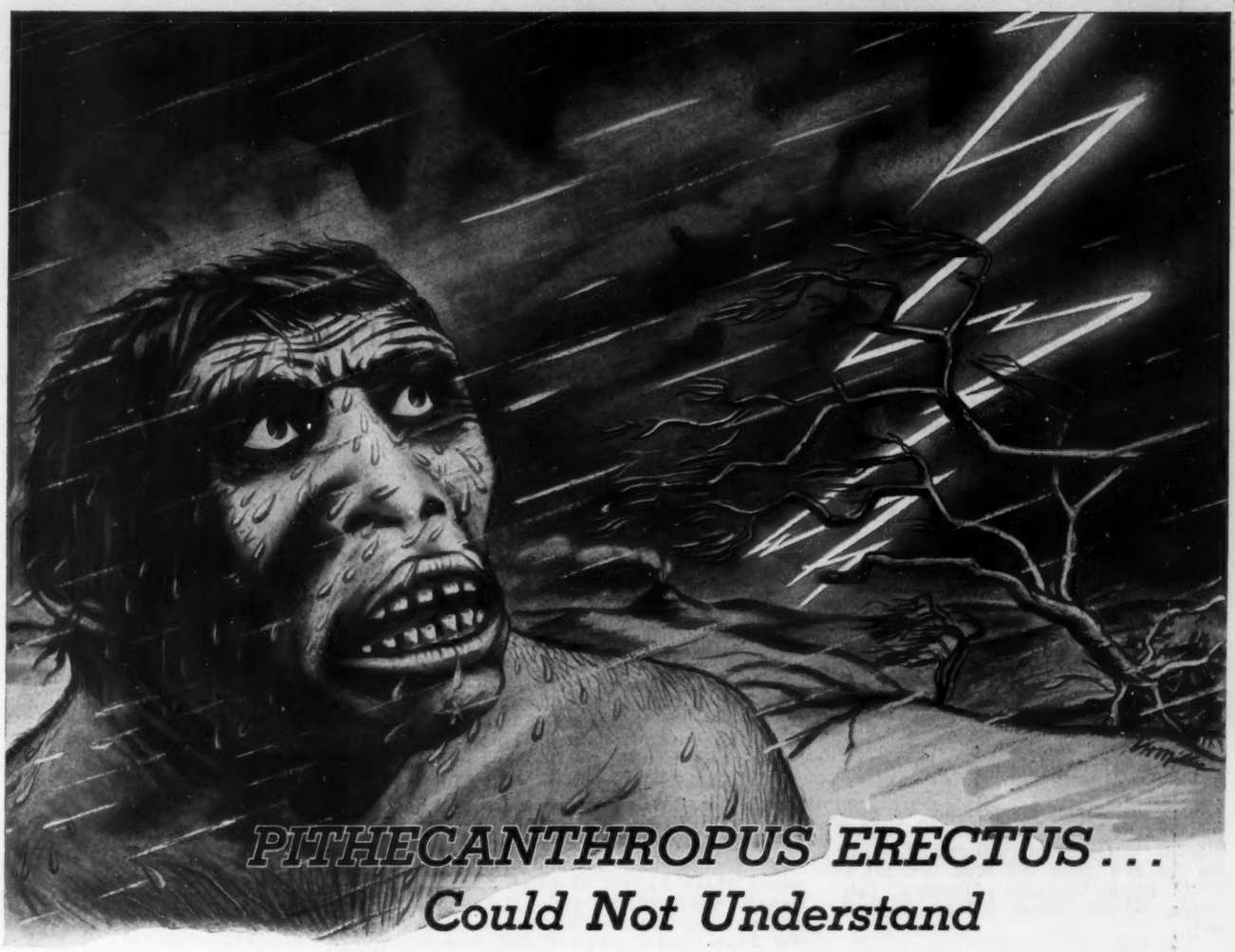
STOCKS OF:	February 8, 1941	February 10, 1940	Percent Change
Gasoline	93,265,000	91,649,000	+ 1.8
Gas Oil & Distillate	36,709,000	26,007,000	+41.1
Residual Fuel Oil	99,921,000	102,344,000	— 2.4
Crude Oil	260,250,000	239,510,000	+ 8.7

LATEST MONTHLY DATA

(Source: Bureau of Mines)

ITEM	Stocks at End of December 1939	1940	Percent Change
SUMMARY—			
Crude Petroleum:			
Refinable in U.S.	239,978,000	264,079,000	+ 10.0
Heavy in California	13,330,000	11,906,000	— 10.7
Natural Gasoline	4,421,000	5,704,000	+ 29.0
Refined Products	268,109,000	282,265,000	+ 5.3
Total, all Oils	525,838,000	563,954,000	+ 7.3
Day's Supply:			
December Basis	132	137	+ 3.8
Year's Basis	135	142	+ 5.2
PRODUCTS—			
Gasoline:			
Finished	77,301,000	77,943,000	+ 0.8
Unfinished	4,421,000	5,704,000	+ 29.0
Total	81,722,000	83,647,000	+ 2.4
Aviation Gasoline (Included above)	2,771,000	6,285,000	+126.8
Kerosene	7,576,000	9,512,000	+ 25.6
*Gas Oil & Distillate Fuels	26,374,000	32,082,000	+ 21.6
*Residual Fuel Oils	87,774,000	83,548,000	— 4.8
Lubricants	7,142,000	8,767,000	+ 22.8
Wax (Pounds)	75,648,000	125,272,000	+ 65.6
Coke (Short Tons)	666,000	487,000	— 26.9
Asphalt (Short Tons)	550,000	614,000	+ 11.6
Road Oil	702,000	624,000	— 11.1
Miscellaneous	276,000	359,000	+ 30.1
Other Unfinished Oils	36,915,000	40,091,000	+ 8.6

* At refineries only.



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fined products imported in 1940 totalled 27,498,000 barrels, up 276.8 percent from 1939. Total imports of all oils was up 93.1 percent from 1939. Much of this volume is due to the pressure of accumulated stocks in South America, a condition which may be expected to prevail for the duration of the war. The 8,258,000 barrels imported during December, 1940, established a new record, the volume being double the average of last winter, and over triple that of the winter season two years ago. The bureau took cognizance of the presence of this large amount of foreign crude in American storage by predicting a run to stills of 3,500,000 barrels during February, 1941, compared to runs of 2,166,000 barrels in February, 1940.

War Caused 47 Percent Reduction in U. S. Oil Exports

ITEM	YEAR 1939	YEAR 1940	Percent Change	MONTH OF DECEMBER 1939	MONTH OF DECEMBER 1940	Percent Change
Crude Oil	72,076,000	51,600,000	— 28.4	4,656,000	2,074,000	— 55.5
Products:						
*Motor Fuel	44,638,000	25,107,000	— 43.8	3,136,000	1,983,000	— 36.8
Aviation Gasoline (included above)	4,234,000	4,295,000	+ 1.4	372,000	497,000†	+ 33.6
Kerosene	8,241,000	3,374,000	— 59.1	652,000	116,000	— 82.2
Gas Oil and Distillate	32,020,000	19,172,000	— 40.1	1,998,000	953,000	— 52.3
Residual Fuel Oil	17,485,000	16,077,000	— 8.1	1,334,000	913,000	— 31.6
Lubricants	11,881,000	10,494,000	— 11.7	1,310,000	588,000	— 55.1
Wax (pounds)	232,644,000	190,035,000	— 18.3	14,603,000	8,778,000	— 39.9
Coke (short tons)	286,200	302,100	+ 5.6	12,600	25,700	+ 104.0
Asphalt (short tons)	42,400	296,800	+ 600.0	2,200	28,700	+1204.5
Miscellaneous Oils	123,000	944,000	+ 667.5	14,000	47,000	+ 235.7
‡Total Refined Products	116,883,000	78,983,000	— 32.4	8,557,000	4,917,000§	— 42.5
Total Crude and Products	188,959,000	130,589,000	— 30.9	13,213,000	6,991,000§	— 47.1

* Includes benzol, 1,000 barrels in December, 1940. † Includes 77,000 barrels anti-knock compounds. ‡ Not the sum of the above figures, some of which do not indicate barrels. § Exclusive of 12,000 barrels exported from non-contiguous territories but inclusive of 457,000 barrels shipped from United States to territories.

Shell Awards Contract for Rubber Ingredient Plant

Shell Oil Company has announced award of a contract for construction of a plant at its Houston refinery for manufacture of butadiene, basic ingredient of synthetic rubber.

Scheduled to be in operation by early summer, the plant will have an annual capacity in excess of 5000 tons. Contract for the new plant has been awarded to C. F. Braun Company, Alhambra, California, and construction will start immediately.

Bureau Reports 1940 Crude Runs 1,294,283,000 Barrels

Total crude runs to stills in 1940 totaled 1,294,283,000 barrels, an increase of 56,443,000 barrels over the preceding year, averaging 3,536,000 barrels a day, it was reported February 18 by the United States Bureau of Mines.

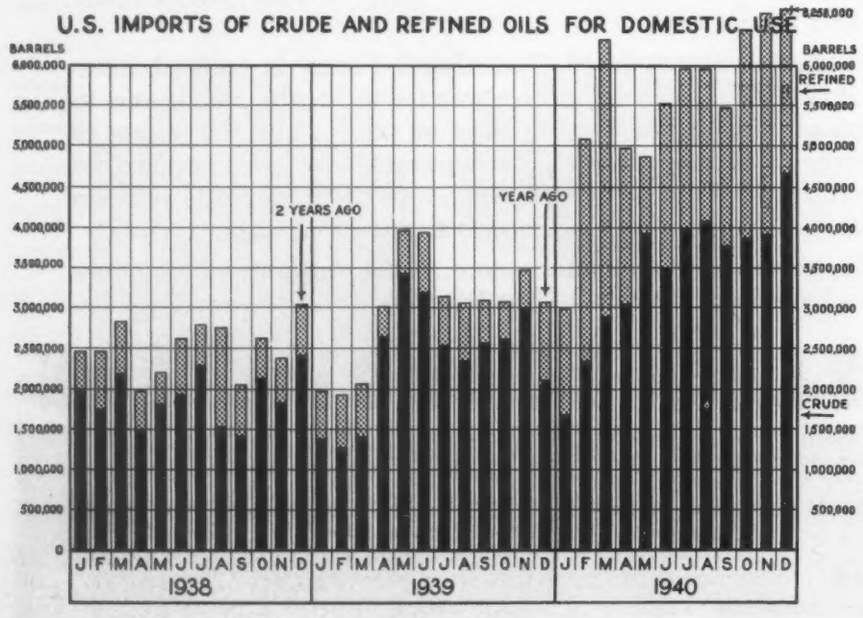
Imports of crude for the year were 42,738,000 barrels, an average of 117,000 barrels a day, with 1,213,000 barrels of the total entered into bond.

December crude runs averaged 3,539,000 barrels a day, an increase of 27,000 barrels over November and 125,000 barrels above the average for December, 1939, the bureau reported. Total runs for the month were 109,703,000 barrels.

Receipts of crude at refineries for the month were 109,293,000 barrels, of which 104,560,000 barrels was domestic and 4,733,000 barrels foreign oil, the report showed. The daily average of receipts was 3,526,000 barrels, of which 3,373,000 barrels was domestic and 153,000 barrels foreign. Fuel and losses were 104,000 barrels, an average of 3000 barrels daily.

For the year, the bureau announced, receipts at refineries included 768,734,000 barrels moving intrastate, an average of 2,100,000 barrels a day; and 487,577,000 barrels moving interstate, an average of 1,332,000 barrels, in addition to foreign oil received. During the year, the entry of foreign oil increased steadily, the December average being slightly more than double that in the corresponding month in 1939.

Stocks of crude at refineries at the close of the year were 52,448,000 barrels, the report showed.


U.S. IMPORTS OF CRUDE AND REFINED OILS FOR DOMESTIC USE
BARRELS
BARRELS
REFINED
CRUDE
2 YEARS AGO
YEAR AGO
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1938
1939
1940

Source: Bureau of Mines

Oil Imports Nearly Double In 1940

Figures indicate barrels and are from Bureau of Mines.

MONTH	Crude Oil	Refined Products	Total
February:			
Feb., 1939	1,266,000	654,000	1,920,000
Feb., 1940	2,343,000	2,731,000	5,074,000
Change	+85.0%	+320.0%	+164.0%
March:			
Mar., 1939	1,404,000	659,000	2,063,000
Mar., 1940	2,895,000	3,410,000	6,305,000
Change	+106.2%	+417.4%	+205.6%
April:			
April, 1939	2,648,000	366,000	3,014,000
April, 1940	3,041,000	1,948,000	4,989,000
Change	+14.8%	+432.0%	+65.5%
May:			
May, 1939	3,434,000	529,000	3,963,000
May, 1940	3,921,000	934,000	4,855,000
Change	+14.2%	+76.5%	+22.5%
June:			
June, 1939	3,196,000	750,000	3,946,000
June, 1940	3,488,000	2,056,000	5,544,000
Change	+9.1%	+174.1%	+40.5%
July:			
July, 1939	2,539,000	608,000	3,147,000
July, 1940	3,981,000	2,000,000	5,981,000
Change	+56.8%	+228.9%	+90.0%
August:			
Aug., 1939	2,346,000	717,000	3,063,000
Aug., 1940	4,074,000	1,898,000	5,972,000
Change	+73.7%	+164.7%	+95.0%
September:			
Sept., 1939	2,553,000	541,000	3,094,000
Sept., 1940	3,772,000	1,712,000	5,484,000
Change	+47.1%	+216.5%	+77.2%
October:			
Oct., 1939	2,605,000	1,741,000	3,965,000
Oct., 1940	3,741,000	3,122,000	6,863,000
Change	+43.6%	+79.3%	+73.1%
November:			
Nov., 1939	2,984,000	482,000	3,466,000
Nov., 1940	3,932,000	2,861,000	6,793,000
Change	—31.8%	+493.6%	+96.0%
December:			
Dec., 1939	2,099,000	958,000	3,057,000
Dec., 1940	4,673,000	3,585,000	8,258,000
Change	+55.1%	+274.2%	+170.1%
Year:			
1939	28,447,000	7,298,000	35,745,000
1940	41,525,000	27,498,000	69,023,000
Change	+46.0%	+276.8%	+93.1%

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Future Role of Residual Fuel Oil

W. B. CASE

THE products derived from petroleum are many and their uses are varied. To list all of them would be a considerable undertaking, particularly as the list grows longer day by day. For several years past, however, the principal products have been gasoline for use in internal combustion motors, kerosene for domestic heating, and, to a considerably lesser extent than heretofore, for lighting; distillate fuel oil used principally for heating and as diesel fuel; lubricants to oil the wheels of industry; residual fuel oil used as a fuel in heavy industry—the railroads, shipping, the oil industry itself, etc., and the solid products wax, asphalt and coke. Strangely enough over the years the supply of these products has been kept in reasonable balance with the demand. At times disequilibrium has occurred and voluntary effort on the part of the industry has been required to restore a balanced condition, but, on the whole, prices operating in a free economy seem to have kept the relative outputs reasonably well balanced.

In discussions of the economics of this amazing industry over the last 30 years, gasoline, as the major product, has received the greatest consideration. In more recent years the widespread use of distillate fuel oil for domestic heating has forced upon the industry the necessity of supplying two "major products" from the same crude. These twins which are taken simultaneously out of the same crude, have proved at times a troublesome pair, as the peak consumption of each occurs during the period of the lowest consumption of the other. However, by judiciously accumulating one while the other is being consumed, the two demands—entirely unrelated one to the other—have been met.

Over the last 40 years at least residual fuel oil has accounted for a substantial percentage of the total output of refined products. Originally produced as an unwanted by-product dumped on the market and destined to be booted around down through the years, it

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nevertheless has had an important effect on the general economy of the industry. It is of great importance today because of the possibility of a substantial increase in consumption of the product by the Navy and by industries engaged in the manufacture of defense materials where residual fuel oil has a decided advantage over other forms of fuel. Consequently, it is in order to give some thought to what might happen should such an increase develop.

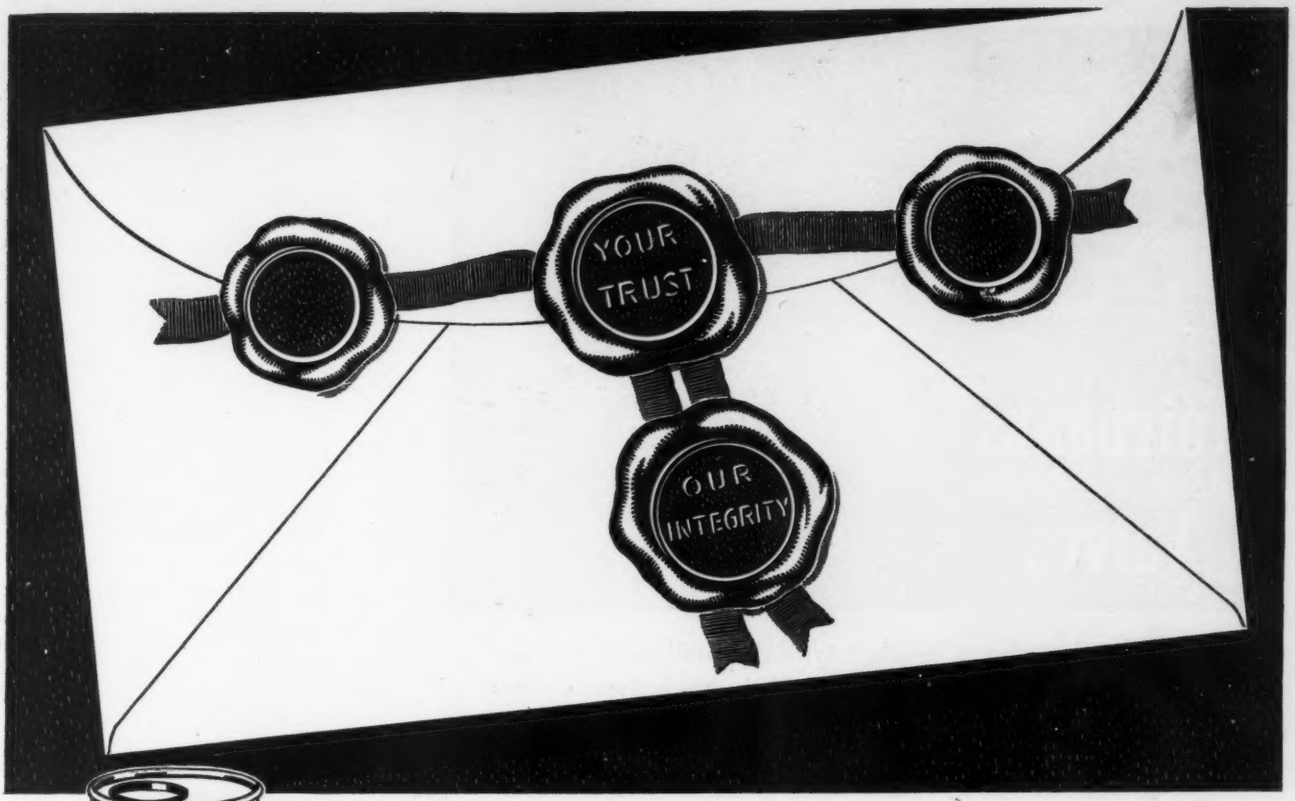
RESIDUAL fuel oil is of special importance now because of the possibility of a substantial increase in consumption by the navy and by industries engaged in manufacture of defense materials where this product has a decided advantage over other forms of fuel. In the face of an indicated continuous decline in the yield of this product, the author points out the several ways by which gains in demand might be met and concludes that the flexibility of the market and the free functioning of price will assure an adequate supply at a reasonable price to "inflexible" consumers. The discussion was presented before the New York Meeting of the American Institute of Mining and Metallurgical Engineers, February, 1941 under title: "The Role of Residual Fuel Oil in the Petroleum Industry."

The question has both near-term and long-term aspects. As to the latter it is reasonable to assume that the yield of residual fuel oil from crude oil will continue to decline as it has over the last 25 years so that regardless of increases that might be expected in the amount of crude refined to meet the major products, no great increase can be expected in the amount of residual fuel oil available. We might inquire, therefore, as to just what the industry's attitude will be toward the additional demand.

Stocks of the product on the East Coast and Gulf Coast at December 31 were adequate and actually about 5,500,000 barrels higher than a year ago. In other refining districts east of California they were about 1,500,000 barrels less than a year ago. In total, east of California, there was an increase in stocks of 4,000,000 barrels. As the domestic demand east of California during 1940 was about 253,000,000 barrels, these additional stocks would supply less than a 2 percent increase in demand. Among the other ways of meeting the increase in demand might be listed the following:

1. Increasing the output of the product by refining more crude oil.
2. Increasing the yield of the product from crude oil.
3. Varying the relative production of high gravity and low gravity crudes.
4. Moving it from California where a surplus exists to the East Coast.
5. Importing additional supplies.
6. Restricting the use of fuel oil to only those users for which other fuels cannot be substituted.

Before examining any of these possibilities, it is worthwhile to see how the increase in demand has been met in the past. In looking over the history of the product, the years up to about 1900 can be ignored. During that time most of the crude oil produced in the United States came from the Appalachian region and was refined al-



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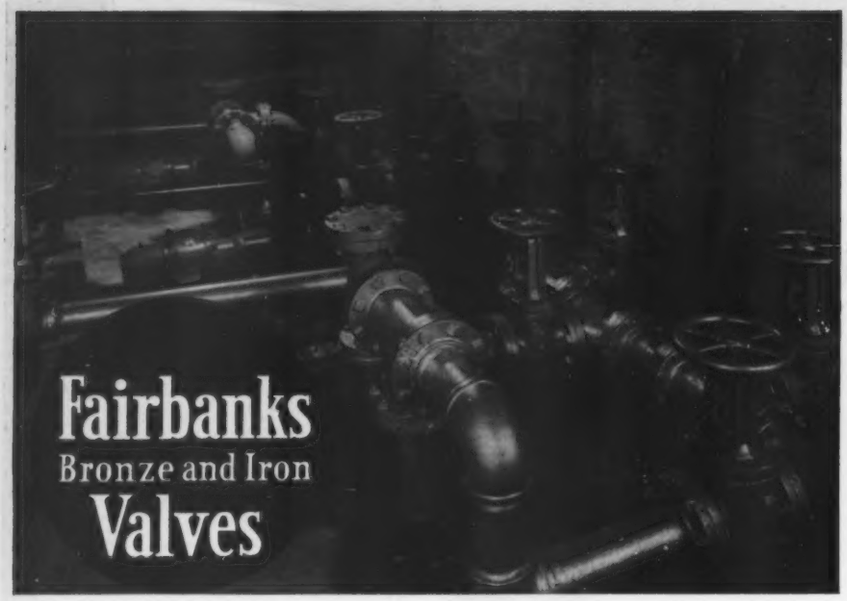

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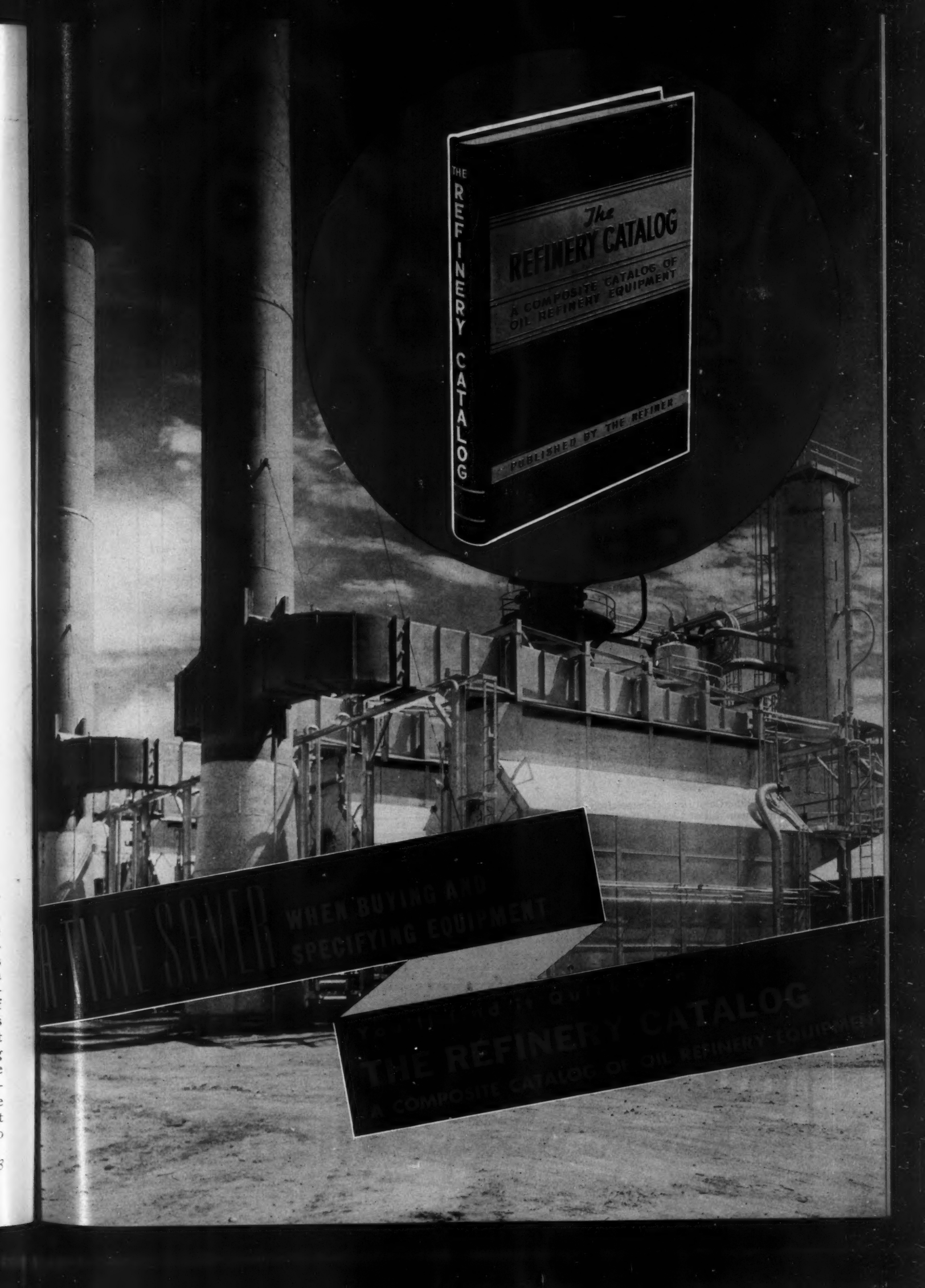
most entirely into gasoline, which was not wanted, kerosene, lubricants and wax. From 1900 to date, the history falls rather naturally into three periods or time divisions, the boundaries of which have not been sharp or distinct. The first period comprises the years 1900 to approximately 1915, during which the production from fields in the southwest and California increased rapidly. This first period closes with the acceptance of the cracking process of refining. The next period is that in which more and more fuel oil was used in cracking stills and ends some time in the 30's, when practically all fuel oil was cracked to some extent. The third period extends up to the present.

Beginning about the turn of the century when mechanical industrialization of the nation was going forward rapidly, the increasing consumption of gasoline and lubricants could be met only by refining additional quantities of crude oil. The discovery and development of the fields in Southwestern States and in California after 1900 resulted in the manufacture of a large supply of residual fuel oil for, with the refining processes existing prior to about 1915, the greater part of the residuum left after distilling off the gasoline and kerosene by straight-run methods was sold as fuel oil. To the extent for which there was a market, some of the residuum was further refined into lubricants, wax, road oil and asphalt.

In this first phase of residual fuel oil history, when the demand for gasoline was growing by leaps and bounds and could be met only by refining additional amounts of crude, the fuel oil had to find a market and mechanical industries which were being created were willing to buy it but only on a strictly heat-content basis. The fuel oil, consequently, had to be sold in competition with coal with little, if any, consideration being given to its advantages as a liquid fuel. The exception to this was the widespread use of fuel oil by railroads in the Southwest and in California where it would have been prohibitively costly to drop supplies of coal along the route of the railways particularly those traversing vast stretches of unsettled land. Along with this use of the product by the railroads other industries soon recognized the advantages of the liquid fuel and beginning about 1910 Mexican oil was imported into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the United States for use principally as fuel. This import movement increased year by year on into the second period of the history.

The second phase in the history of the product began with the acceptance of cracking as a refining method some time about 1915. After the potentialities of residuum as a source of gasoline had been recognized there was an ever-increasing use of residual fuel oil as a charging stock to cracking plants and the end of the second period occurred some time in the 30's when straight-run residual fuel oil practically ceased to be marketed east of California. During this second period the increase in the demand for gasoline continued to require greater and greater amounts of crude oil and as mentioned, imports from Mexico continued to increase. During the year 1921 imports into the United States were equal to more than 26 percent of the domestic production. Late in 1922 the supply was further augmented substantially by shipments of California crude through the Panama Canal following the discovery of the prolific fields in the Los Angeles Basin, the oil from which contains a large percentage of residual fuel. At about the same time the great Smackover field was discovered and much of its low-gravity production was burned as fuel oil.

It might be well to note at this point that except for the years 1922 to 1926, California supplies of

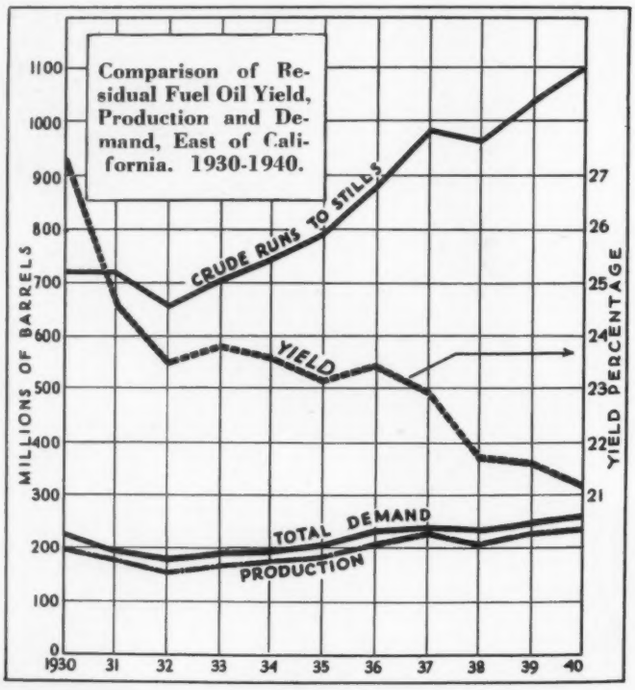

FIGURE 1

Crude Oil Runs to Stills, Residual Fuel Oil Yield, Refinery Output of Residual Fuel Oil and Total Demand for Residual Fuel Oil—All East of California for Years 1930 to 1940 Inclusive.

	Runs To Stills 1000 Barrels	Residual Fuel Oil Yield Percent	Refinery Output of Residual Fuel Oil 1000 Barrels	Total Demand For Residual Fuel Oil—Domestic & Export 1000 Barrels
1930	722,619	27.3	197,312	225,797
1931	721,600	24.6	177,450	199,009
1932	655,260	23.5	154,251	179,569
1933	703,996	23.8	167,618	188,846
1934	739,301	23.6	174,381	189,917
1935	787,939	23.1	181,607	201,473
1936	878,827	23.4	205,607	228,480
1937	980,295	22.9	224,364	237,870
1938	964,681	21.7	208,849	230,624
1939	1,039,186	21.6	224,962	248,750
1940	1,093,260	21.2	232,525	257,534

Source: U. S. Bureau of Mines Reports.

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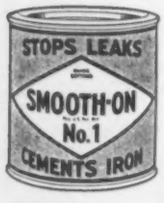

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crude oil and residual fuel oil have had little effect on the industry east of California and in any discussion of residual fuel oil the two areas, namely, Pacific Coast states and east of California, might better be thought of as separate and distinct provinces. There has been some eastward movement of California residual fuel oil in recent years but in spite of the tremendous surplus of the product in California, shipments in each of the last six years have amounted to less than one million barrels a year. Of vastly more importance has been the effect of the world wide market on both of these provinces. In California, today, the stocks of residual fuel oil and non-gasoline-bearing crude oil suitable for use as fuel oil, amount to more than 70 million barrels and there is no problem whatever in meeting any conceivable increase in demand. The remainder of the discussion, therefore, will be confined to that part of the United States east of California.

Although separate figures for distillate and residual fuel oil are not available prior to 1930, the combined statistics prior to that date indicate that the demand for residual fuel oil increased steadily up to the year 1929 and this in face of a declining percentage yield from crude. During the depression years 1930 to 1933 the trend of demand was downward but with the recovery it turned upward again in 1934 to 1937. Nineteen hundred and thirty-eight again saw a reversal but increases in 1939 and 1940 brought the domestic demand for the product to an all-time high of approximately 252,700,000 barrels east of California (335,600,000 barrels for the United States). The increase in demand from 1930 to 1940 like the increase prior to 1930 has been accompanied by a con-

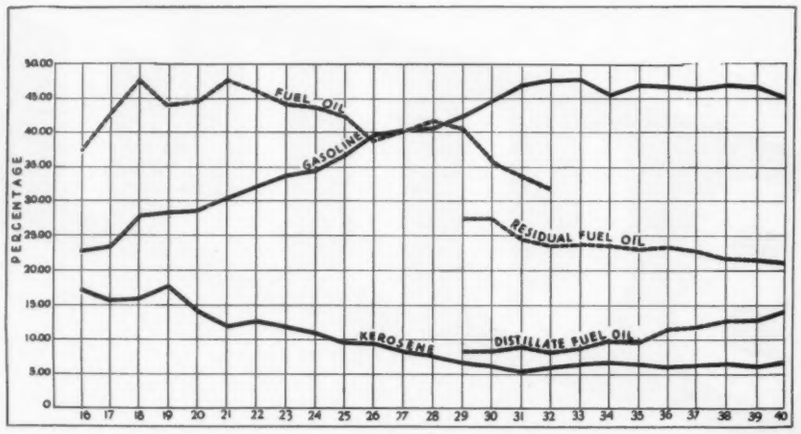

FIGURE 2

Yields of Principal Products from Crude Oil East of California 1916 to 1940

	Gasoline Percent	Kerosene Percent	Dist. F. O. Percent	Res. F. O. Percent	Total F. O. Percent
1916	22.09	17.16	....	....	37.35
1917	23.61	15.61	....	....	42.73
1918	27.92	15.80	....	....	47.59
1919	28.29	17.64	....	....	43.95
1920	28.46	14.08	....	....	44.37
1921	30.28	11.87	....	....	47.47
1922	32.18	12.64	....	....	45.95
1923	33.59	11.78	....	....	44.05
1924	34.52	10.70	....	....	43.64
1925	36.73	9.59	....	....	42.27
1926	39.53	9.45	....	....	38.93
1927	40.13	8.15	....	....	40.04
1928	40.89	7.26	....	....	41.53
1929	42.22	6.38	....	....	40.88
1930	44.15	5.94	8.38	27.31	35.68
1931	46.6	5.3	8.9	24.6	33.5
1932	47.3	5.8	8.1	23.5	31.6
1933	47.4	6.2	8.7	23.8	32.5
1934	45.7	6.5	9.9	23.6	33.5
1935	46.8	6.4	9.81	23.05	32.8
1936	46.3	5.9	11.4	23.4	34.8
1937	46.1	6.1	12.0	22.9	34.9
1938	46.7	6.3	12.7	21.7	34.4
1939	47.2	6.1	12.7	21.6	34.3
1940	45.2	6.5	14.2	21.2	35.4

Source: U. S. Bureau of Mines Report.

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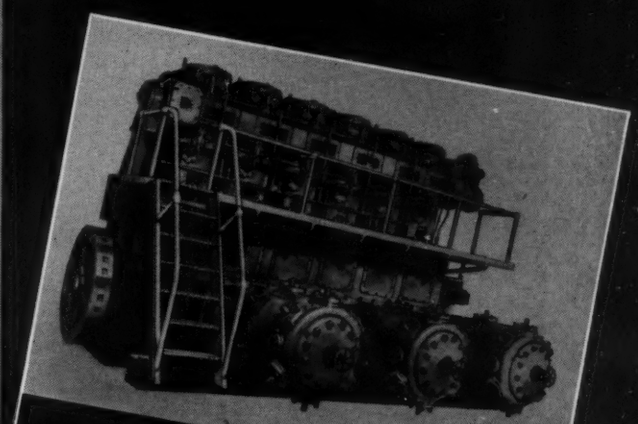

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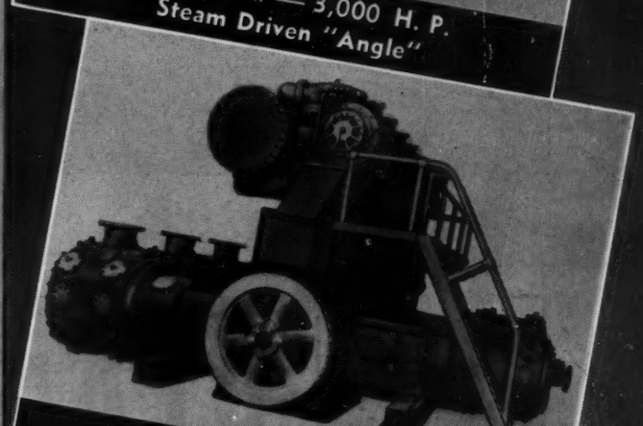

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stantly declining percentage yield from crude.

Figure 1 and Table 1 show the relationship between the total demand, domestic and export, for residual fuel oil east of California and the yield from crude. Also shown are the runs to stills and the refinery production of the product.

Figure 2 and Table 2 show the yields of the principal products obtained from crude oil during the years 1916 to 1940 inclusive—the second and third periods in the product's history. Yields of all fuel oils — distillate and residual — decreased from 47.6 percent in 1918 to 35.7 percent in 1930. The reduction in the yield of residual fuel oil was more pronounced than is indicated by these figures because of the increase in distillate fuel oil that must have occurred during this period. Although statistics are not available on the output of distillate fuel oil in 1918 it is known that their use was limited and it probably is fair to say that the yield of residual fuel oil decreased from approximately 45 percent in 1918 to the statistically recorded 27.3 percent in 1930. The yield continued to decline to 21.2 percent in 1940—less than half the 1918 percentage yield.

In the third or present-day phase of the product, the use of residual fuel oil can be thought of as being composed of two parts—the one flexible, that is, susceptible of being replaced by substitute fuels; and the other inflexible, that is, not readily susceptible to replacement. Among the inflexible consumers are most of the railroads now using the fuel, to some extent the oil companies themselves and a part of those who use the product for heating. The use of the fuel in ships is, of course, most inflexible but those engaged in international trade can buy elsewhere than in the United States if the price at another port of call is more attractive. The flexible users are the gas and electric power plants and most industries. Figure 3 and Table 3 show the distribution of the use of residual fuel oil. (Figure 3 for the year 1939 east of California only.) For the year 1939 (the last year for which actual figures have been published) the use in ships accounted for over 19 percent of the total consumption. The railroads used 14.7 percent of the total and 14.2 percent was used for heating. Industries, other than railroads, gas and electric power plants used 21

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percent and the oil industry itself was one of its own good customers and used 15.7 percent of the total. The inflexible use of the fuel would appear, therefore, to include much of the 19.4 percent used by ships, the greater part of the 14.7 percent used by the railroads, some portion, perhaps half of the amount used for heating and the larger proportion of the amount used in the oil industry or roughly about 50 percent of the total. Thus, the flexible use is about equal to the inflexible use.

The inflexible use of the product is related very closely to general industrial conditions. The flexible use is related almost entirely to price and is in fact more sensitive to the effect of price than are any of the other principal petroleum products. Thus, there was a reduction in the use of fuel oil by railroads and ships in 1938 as compared to 1937 paralleling the decline in business activity. The gas and electric power plants, however, used less in 1937 than in 1936 but increased their use in 1938. Their reduced consumption in 1937 was doubtless the result of the high prices which existed in that year and ran counter to trend of industrial production.

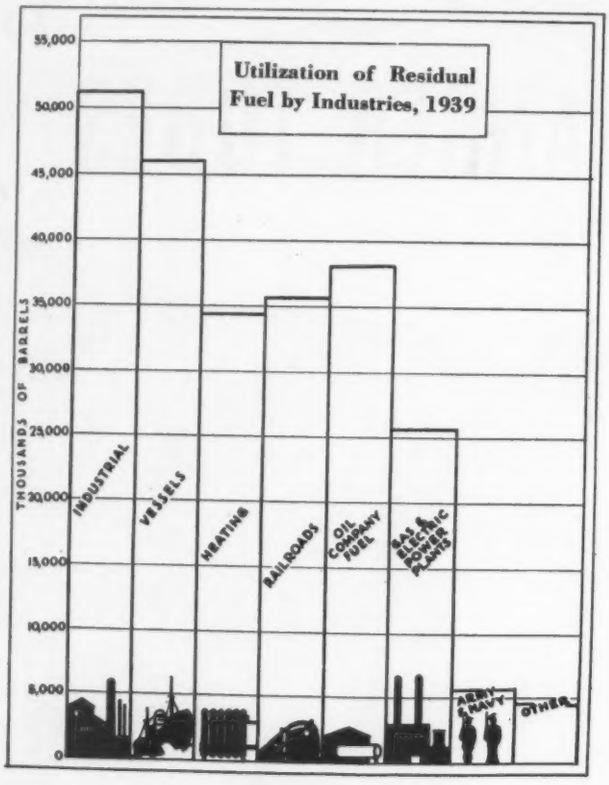

FIGURE 3

Distribution of Use of Residual Fuel Oil

	1936* 1000 Barrels	1937 1000 Barrels	1938 1000 Barrels	1939 1000 Barrels	1939 Percent Total	1940* 1000 Barrels
East of California:						
Heating No. 5 & No. 6....	25,031	29,525	31,157	34,502	14.22	40,000
Railroads.....	35,500	38,605	32,439	35,669	14.70	36,000
Vessels.....	47,300	52,120	46,230	47,191	19.44	46,000
Gas & Elec. Pow. Plants...	21,500	19,914	21,118	25,611	10.55	27,000
Other Industries.....	55,200	57,640	46,787	51,253	21.12	55,000
Navy, Army & C. G.....	2,500	3,177	4,563	5,507	2.27	6,000
Oil Company Fuel.....	40,900	36,573	36,384	38,190	15.73	38,000
Miscellaneous Uses.....	2,300	3,784	3,176	3,646	1.50	4,722
Unaccounted for.....	4,890†	6,543†	1,385	1,143	.47	....
Total.....	225,341	234,795	223,239	242,712	100.00	252,722
Pacific Coast Territory:						
Heating No. 5 & No. 6....	4,367	5,857	4,778	4,599	5.97	4,500
Railroads.....	24,800	29,224	23,670	25,308	32.85	28,500
Vessels.....	19,700	19,376	14,948	17,955	23.31	20,000
Gas & Elec. Pow. Plants...	2,000	3,607	2,764	2,297	2.98	2,500
Other Industries.....	10,200	11,467	8,027	9,598	12.46	11,000
Navy, Army & C. G.....	6,500	5,615	6,411	5,652	7.34	6,000
Oil Company Fuel.....	4,100	3,622	4,130	7,833	10.17	8,000
Miscellaneous Uses.....	4,000	3,127	1,763	1,344	1.74	2,433
Unacct'd for & Diesel Fuel.	6,876	8,824	2,103	2,440	3.18	....
Total.....	82,543	90,719	68,594	77,026	100.00	82,933
United States:						
Heating No. 5 & No. 6....	29,398	35,382	35,935	39,101	12.22	44,500
Railroads.....	60,300	67,829	56,109	60,977	19.07	64,500
Vessels.....	67,000	71,496	61,178	65,146	20.37	66,000
Gas & Elec. Pow. Plants...	23,500	23,521	23,882	27,908	8.73	29,500
Other Industries.....	65,400	69,107	54,814	60,851	19.03	66,000
Navy, Army & C. G.....	9,000	8,792	10,974	11,159	3.49	12,000
Oil Company Fuel.....	45,000	40,195	40,514	46,023	14.39	46,000
Miscellaneous Uses.....	6,300	6,911	4,939	4,990	1.56	7,155
Unaccounted for.....	1,986	2,281	3,488	3,583	1.14	....
Total.....	307,884	325,514	291,833	319,738	100.00	335,655

Source: Bureau of Mines except as noted:
* Estimates by Author. † Denotes Red Figure.

The question of proper and improper uses or, as sometimes disguised, superior and inferior uses of residual fuel oil has been raised on many occasions in recent years. It is rather difficult to define a proper or superior use of the product. In the light of present-day conditions, the use of uncracked residuum and of vast quantities of refinable crude oil such as were burned in the years 1900 to 1915, would doubtless be considered improper; but conditions which existed at that time put an entirely different aspect on the practice. The manufacture and sale of cracked residuum today is purely a question of refining economics. A refiner might be equipped to crack his light oils to gasoline and heavy fuel oil or to run to coke but if the final stages of cracking cost more than the value of the products which he recovers, he will sell his residuum as fuel oil.

It is not the present purpose to unearth an old bone of contention as to proper or superior and improper or inferior uses. It seems of much greater importance that about half the demand can be filled by substitute fuels and that this half will switch to other fuels whenever the equivalent heat content can be obtained from them at lower cost. It must also be borne in mind that the price of crude oil acts as a ceiling for the price of residual fuel oil and that crude prices do affect the demand for residual fuel oil.

It has been pointed out that over the years, in spite of the increasing demand for residual fuel oil the industry continuously has reduced the percentage yield from crude oil and has met the mounting demand by other means — imports, shipments from California and the use of low-grade crude oil. The statis-

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tics of the industry do not yield any evidence that the industry as a whole has ever sought to increase its output of residual fuel oil by refining additional quantities of crude oil. It is understandable that in isolated instances some refiner having an order for heavy fuel oil for which he would not have the necessary supplies, might have stepped up his runs temporarily knowing that he would have a market for the other products but such a practice has never prevailed throughout the industry. Rather the attitude seems to have been that the industry would supply whatever quantities of heavy fuel it found necessary to make in supplying the markets for gasoline, kerosene and distillate fuels and that any demand for the product beyond that would have to be filled from supplies obtained from other sources which up to the present have always been available. This attitude on the part of the industry coupled with the flexibility of half the demand, the ever present alternative of importing supplementary supplies and the normal functioning of price has operated to keep demand and supply in balance. In other words, demand for residual fuel oil has not functioned in the determination of the required runs of crude to stills nor in the demand for crude oil. From the standpoints of industry economies, social economics and conservation of our petroleum resources it is proper that it should not. So long as runs to stills are regulated to meet the demand for gasoline and distillate fuel oil, with equilibrium between these products maintained by regulating the yields and accumulation of stocks in the "off" season, the respective demands for these essential products for which there is no acceptable substitute can be met from a predetermined quantity of crude oil. But were the industry to attempt to bring into the determination of the required runs to stills such a nebulous factor as that of supplying a by-product to be used in destructive price competition with other fuels, the supply of the essential products would greatly exceed the demand, our valuable reserves of petroleum would be depleted needlessly and chaotic conditions doubtless would result. The oil industry has never done this.

Of the six methods suggested earlier for balancing supply and demand it thus appears that the first two namely (1) increasing the output of residual fuel oil by refining more crude and (2) increasing the yield, are contrary to the progressive principles which the industry has followed over the years.

The third proposal, namely that of varying the production of high-gravity and low-gravity crudes seasonally has many merits. However, the seasonal change in the relative quantities to be produced from the wells can be obviated by storing the low-gravity crude in the summer for use in the winter and vice versa for the high gravity. Insofar as the balance between gasoline and distillate fuel oil is concerned, the industry has solved the problem by seasonal variation in yields and accumulation of adequate stocks. The proposal has found its greatest objection in the inequities that would result in the administration of proration. In any event, inasmuch as the seasonal variation in production is actually unnecessary, it seems reasonable to assume that if a greater year-round demand for these low-gravity crudes did actually exist, it would be reflected in today's proration schedules.

The possibility of moving residual fuel oil from California depends, of course, entirely on tanker rates, the availability of boats and the price to be ralized in the Eastern market. With tanker rates as they are today such a movement is unprofitable as it amounts to nearly two and a half times the cost of bringing supplies from the Gulf Coast or from the refineries in the Caribbean. The cost of moving supplies from these latter refineries to the eastern seaboard for use in ships engaged in foreign trade is not prohibitive even with present tanker rates. Such a movement releases for domestic use an equivalent amount of the fuel; it may be expected that it will continue at a high level.

From what has gone before it seems clear that the sixth proposal namely restricting use need not arise. The flexibility of the market and the free functioning of price will assure an adequate supply.

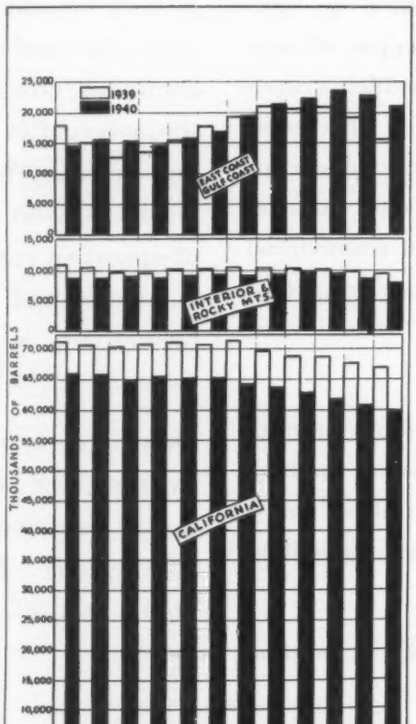

FIGURE 4

Refinery Terminal and in Transit Stocks of Residual Fuel Oil—1939 and 1940

	Jan. 1	Jan. 31	Feb. 28–9	Mar. 31	April 30	May 31	June 30	July 31	Aug. 31	Sept. 30	Oct. 31	Nov. 30	Dec. 31
1939:													
East Coast-Gulf Coast	23,076	17,295	15,076	12,788	13,434	15,513	17,376	19,453	21,239	20,949	21,163	19,261	15,768
Interior & Rocky Mountain	12,266	11,059	10,567	9,826	9,760	10,143	10,187	10,431	10,336	10,272	10,110	9,987	9,629
California	70,755	71,239	70,642	70,480	70,877	71,088	70,842	71,280	69,786	68,842	68,648	67,448	66,893
Total United States	106,097	99,711	96,285	93,094	94,071	96,744	98,405	101,164	101,361	100,063	99,921	96,696	92,290
1940:													
East Coast-Gulf Coast	15,768	14,639	15,489	15,398	14,808	15,801	17,002	19,665	21,475	22,385	23,448	22,916	21,238
Interior & Rocky Mountain	9,629	8,647	8,656	8,998	8,774	8,940	9,037	9,018	9,371	9,732	9,439	8,722	8,174
California	66,893	65,995	65,639	64,955	65,350	65,094	65,109	64,346	63,575	62,830	61,771	60,754	59,892
Total United States	92,290	89,281	89,784	89,351	88,932	89,835	91,148	93,029	94,421	94,947	94,658	92,392	89,304

Source: U. S. Bureau of Mines Reports.

Bureau Ups March Demand 26,600 Barrels Over February

Market demand for petroleum products next month will require production of domestic crude oil at a rate of 3,655,500 barrels a day, it was forecast February 20 by the United States Bureau of Mines.

The March forecast is 26,600 barrels higher than the estimated demand for this month, but 14,900 barrels lower than the actual demand in March, 1940, when a heating oil shortage caused by the extremely cold winter resulted in large runs of crude oil to stills, it was pointed out.

Analysis of the bureau's forecasts for the past 15 months, however, shows that the March figure is the highest since that for August, 1940, and there is little doubt that oil production in the United States is heading toward new high levels.

The bureau reported that daily average crude-oil production during the four weeks, January 11 to February 8, was 3,605,000 barrels, and runs to stills 3,609,000 barrels, while during the period domestic crude stocks increased an average of 48,000 barrels daily, indicating a demand of 3,557,000 barrels.

"Current data indicate an increase in the total demand for all oils that verifies the bureau's long-term estimates as published in the January forecast report," it was commented. "As pointed out at that time, only a moderate rate of increase in total demand for the first quarter of 1941 could be expected because of the exceptionally high demand in the same period of 1940.

"An analysis of current data, as compared with the same period last year, indicates that the domestic demand for motor fuel may be greater than anticipated, that the domestic demand for distillate fuel oils will be no greater, and possibly less, than the abnormal demand for the first quarter of last year, when a gain of 25 percent over 1939 was recorded; that the domestic demand for residual fuel oils will show a moderate increase over the exceptionally high figures of last year; and that the total volume of exports has declined, while imports of crude and residual fuel have increased substantially."

Motor Demand Up 8 Percent

Domestic demand for motor fuel in March is estimated as 48,200,000 barrels, or eight percent above the actual demand in the same month last year. The estimate for exports, based upon forecasts by the principal exporters, is 2,000,000 barrels, compared with an actual export of 1,983,000 barrels in December and 2,265,000 barrels in March, 1940.

Stocks of finished and unfinished gasoline amounted to 84,809,000 barrels on December 31, or about 1,500,000 barrels higher than they were at the end of 1939, it was pointed out. Statistics of the American Petroleum Institute indicate an increase of about 6,900,000 barrels during January, which would bring them to near 91,300,000 barrels as of January 31. The bureau estimates a further increase of 2,600,000 barrels during March which, together with the estimated February increase, if adhered to, would make the March 31 inventory of finished and unfinished stocks approximately 100,000,000 barrels.

Benzol production and direct sales of natural gasoline are estimated as 1,600,000 barrels, which would give an indicated refinery production of 51,200,000 barrels, which the bureau distributed among the several districts as follows:

East Coast, 6,760,000 barrels; Appalachian, 1,930,000 barrels; Indiana-Illinois, 11,250,000 barrels; Oklahoma, 2,690,000 barrels; Kansas-Missouri, 2,840,000 barrels; Inland Texas, 3,420,000 barrels; Texas Gulf Coast, 12,220,000 barrels; Louisiana Gulf Coast, 1,410,000 barrels; Inland Louisiana-Arkansas, 910,000 barrels; Rocky Mountain, 1,390,000 barrels; California, 6,380,000 barrels.

Natural gasoline to be blended at refineries is estimated as six percent of the total refinery production, or 3,070,000 barrels. The yield of straight-run and cracked gasoline is estimated as 43 percent which, applied to the production of 48,130,000 barrels, gives crude runs of 111,920,000 barrels, or 3,610,300 barrels daily.

The estimate for foreign crude runs to stills is 3,900,000 barrels, compared with actual runs of 2,348,000 barrels in March of last year. The estimate for crude-oil exports, in keeping with a less optimistic outlook by the principal exporters, has been lowered to 3,200,000 barrels, compared with actual exports of 4,046,000 barrels last year, Crude oil to be used as fuel and losses is estimated as 2,100,000 barrels.

On the basis of these estimates, the total demand for domestic crude oil in March is placed by the bureau at 113,320,000 barrels, or 3,655,500 barrels a day, which it has allocated among the several states as shown in an accompanying table.

The Look Box

Bureau of Mines Forecast of Crude Oil Demand for March

State	Forecast March 1941	Forecast February, 1941
Texas	1,327,400	1,312,900
California	596,400	595,700
Oklahoma	437,400	442,500
Illinois	335,200	342,100
Louisiana	291,300	288,600
Kansas	194,200	193,200
New Mexico	103,900	100,700
Wyoming	83,900	74,600
Arkansas	69,700	66,100
Pennsylvania	48,100	50,000
Michigan	47,400	47,500
Indiana	22,600	22,500
Montana	21,900	20,000
Mississippi	20,300	16,100
Kentucky	14,200	15,400
New York	13,000	12,900
West Virginia	11,100	10,900
Ohio	10,100	10,100
Colorado	3,900	3,900
Nebraska	3,200	3,200
	3,655,500	3,628,900

CONVENTIONS

MAR. 13–14	Society of Automotive Engineers, National Aeronatuic Meeting, Washington Hotel, Washington.
14	Ark-La-Tex Division, Western Petroleum Refiners Association, Washington-Youree Hotel, Shreveport.
17–22	Oil Burner Institute's National Oil Burner Progress Exhibition, Commercial Museum, Philadelphia.
APR. 7–11	American Chemical Society, St. Louis.
9–10	Midwest Power Conference, Palmer House, Chicago.
15–17	Southwest Gas Measurement Short Course, University of Oklahoma, Norman.
23–25	Natural Gasoline Association of America, Annual Meeting, Baker Hotel, Dallas.
23–25	Petroleum Industry Electrical Association, Mayo Hotel, Tulsa.
24–25	National Petroleum Association, Cleveland Hotel, Cleveland.
MAY 2– 3	Petroleum and Natural Gas Conference, State College, Pennsylvania.
5– 8	American Gas Association, Natural Gas Section, Dallas.
19–21	American Institute of Chemical Engineers, Semi-Annual Meeting, Edgewater Beach Hotel, Chicago.
19–22	American Petroleum Institute, Mid-Year Meeting, Mayo Hotel, Tulsa.
JUNE 16–12	Petroleum Division, American Society of Mechanical Engineers, Kansas City.
23–27	American Society for Testing Materials, Annual Meeting, Palmer House, Chicago.

Arkansas Joins Oil Compact

Arkansas became the seventh member of the Interstate Oil Compact Commission in February when Governor Bailey signed a bill previously passed by the legislature. Membership in the compact was rejected by the Wyoming legislature.

Compact membership has been on a two-year basis by most states, with the legislatures extending the legislation at each regular session. Kansas continued its membership by such an extension last month.

Pennsylvania Group To Meet in Bradford

The annual meeting of the Pennsylvania Grade Crude Oil Association will be held in Bradford, June 19 and 20. The program, now being prepared, will include a luncheon the first day with an association meeting that afternoon and the following morning. A dinner meeting will be held the evening of the first day and the session will close with a luncheon the last day.

Complete Plans for Gas Measurement Short Course

Approval of the program for the seventeenth annual Southwestern Gas Measurement Short Course, Norman, Oklahoma, April 15-17, came March 10, when the committee met in Tulsa to go over the final draft, submitted by G. W. McCullough, Phillips Petroleum Company, chairman.

Previously the entire committee met in Norman to go over general arrangements. Plans have been made to accomodate more than 650 persons. Attendance in 1940 was 670, who came from 20 states as well as from Canada and Mexico. Since the course was started, attendance has totaled 8392, representing 644 companies.

Chairmen of the various committees are: Ray L. Rountree, United Gas Pipe Line Company, Shreveport, general

Committee meeting of the Southwestern Gas Measurement Short Course which will be held at the University of Oklahoma, Norman, April 15, 16 and 17.
In attendance, left to right, standing: W. H. Carson, E. M. Myers, E. C. McAninch, Max K. Watson, J. H. Page, J. H. Satterwhite, William F. Lowe, W. R. McLaughlin, R. M. Scofield, E. L. Stark. Left to right, sitting around the table: Gilbert Estill, Earl Kightlinger, C. A. Gibson, Ray L. Rountree, G. W. McCullough, D. A. Sillers and Kate A. Niblack.
Other members of the General Committee not present for the picture are: Dr. F. V. L. Patten, E. H. Poe, R. J. Sullivan, C. E. Terrell and W. H. Woods.

chairman; G. W. McCullough, Phillips Petroleum Company, Bartlesville, program; W. H. Carson, dean of the College of Engineering, University of Oklahoma, banquet and entertainment; Earl Kightlinger, Arkansas Louisiana Gas Company, Shreveport, publications; C. A. Gibson, Cities Service Gas Company, Bartlesville, exhibits; R. M. Scofield, Lone Star Gas Company, Dallas, study of practical methods; Miss Kate A. Niblack, Oklahoma Utilities Association, Oklahoma City, registration and publicity.

Committee chairmen together with the following, comprise the general committee: William Lowe, secretary, Natural Gasoline Association of America, Tulsa; E. C. McAnnich, Oklahoma Natural Gas Company, Tulsa; W. R. McLaughlin, Pittsburgh Equitable Meter Company, Dallas; E. M. Myers, Corporation Commission of Oklahoma, Oklahoma City; J. H. Page, Kansas Corporation Commission, Wichita; F. V. L. Patten, Railroad Commission of Texas, Austin; E. H. Poe, natural gas section, American Gas Association, New York; J. H. Satterwhite, American Meter Company, Tulsa; E. L. Stark, Foxboro Company, Dallas; R. J. Sullivan, Humble Oil & Refining Company, Houston; C. E. Terrell, Southern Natural Gas Company, Birmingham; Max K. Watson, Canadian River Gas Company, Amarillo, and W. H. Woods, Gulf Oil Corporation, Houston.

Oil and Gas for Metal Congress

Particular attention will be given to metals used in the manufacture of equipment for refining and natural gas operations as part of the program of the Western Metal Congress and Metal Exposition, Los Angeles, May 19-23. The California Gas and Oil Association, Pacific Coast Gas Association and western branches of the Liquefied Petroleum Gas Association are among organizations cooperating with the American Society of Metals in carrying out the program.

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John R. Suman Elected President of A.I.M.E.

John R. Suman, vice president of Humble Oil & Refining Company, Houston, was elected president of the American Institute of Mining and Metallurgical Engineers at the annual meeting in New York, February 17 to 20. He is the fourth man from the petroleum industry to serve in this capacity.

Chairman for the petroleum section is Eugene A. Stephenson, professor of Petroleum Engineering, University of Kansas, Lawrence. This division will have three associated chairmen for the year: R. B. Kelly, The Pure Oil Company, Olney, Illinois; V. C. Smith, Charleston, West Virginia; and H. P. Stolz, Stanley & Stolz, Los Angeles. The executive committee for the division includes Dr. Stephenson, as chairman; C. J. Coberly, W. H. Geis, W. B. Heroy, D. R. Knowlton and T. V. Moore. Harold Vance, Texas A. & M. College, College Station, is secretary-treasurer and Chester Naramore, New York, is executive secretary.

Chairmen of the standing committees are: W. S. Morris, East Texas Engineering Association, Kilgore, papers and programs, with L. E. Porter, Richfield Oil Corporation, Los Angeles, as vice chairman; A. W. Walker, Stanolind Oil & Gas Company, Tulsa, production engineering; J. Terry Duce, California Arabian Standard Oil Company, San Francisco, production, with M. T. Halbouty, Houston, and Basin Zavoico, New York, as vice chairmen; L. F. Terry, Chase National Bank, New York, economics; A. D. Garrison, The Rice Institute, Houston, engineering research; Walter Miller, Continental Oil Company, Ponca City, refinery engineering; C. A. Warner, Houston Oil Company of Texas, Houston, membership; H. H. Power, University of Texas, Austin, nominations.

The program of the petroleum division for the recent meeting began February 18 and continued through February 20. Abstracts of papers of interest to the manufacturing division of the petroleum industry follow:

World Consumption of Petroleum and Its Substitutes in 1940

By V. R. Garfias, R. V. Whetsel and J. W. Ristori,
Cities Service Company, New York

World consumption of petroleum and its substitutes in 1940, which with the exception of the United States, *does not include consumption for military purposes even in peacetime,* is estimated at 2,006,000,000 barrels or approximately 21,000,000 barrels less than in 1939. As

V. R. Garfias

J. W. Ristori

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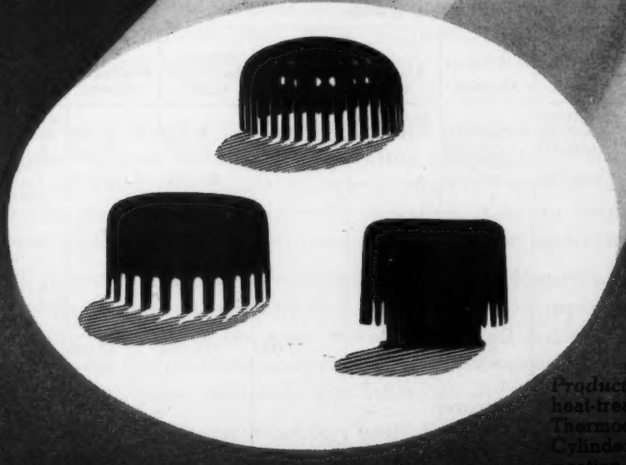

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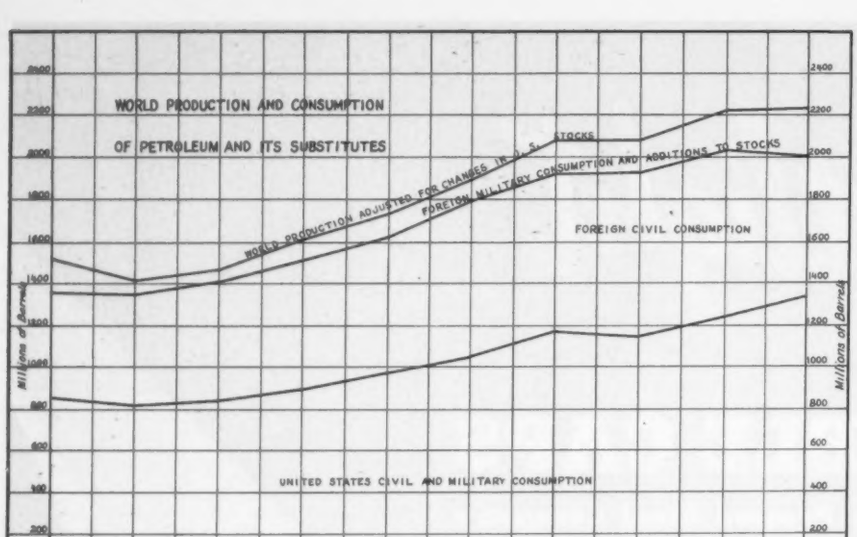


consumption figures for belligerent countries and those affected by the war are unavailable, in order to arrive at a gross approximation the assumption has been made that the rate of civil consumption in these countries has declined 80 percent since the German occupation or the effect of the war made itself felt.

In 1940 the total consumption in the United States increased 94,000,000 barrels over the previous year while the civil consumption in the countries directly affected by the war—some of them occupied during the last half of the year—decreased 126,000,000 barrels. In the rest of the world consumption increased 11,000,000 barrels, resulting in an overall decrease in world civil consumption grossly estimated at 21,000,000 barrels.

Although no reliable information is available regarding military consumption in foreign countries before or during the war, military consumption and/or addition to stocks in foreign countries in 1940, as shown in Table 1, are roughly estimated at 221,000,000 barrels or about 35,000,000 barrels more than in 1939. The peacetime consumption for military purposes of these countries has been previously roughly estimated at 47,500,000 barrels.

World Production of Petroleum Substitutes

By V. R. Garfias
and
R. V. Whetsel

Cities Service Company,
New York, New York

World production in 1939 of petroleum substitutes, of which 97 percent constituted direct substitutes for motor fuel, amounted to about 108,000,000 barrels, or 300,000 barrels daily, equivalent to aggregate crude oil output in that year in Rumania, Mexico, and Colombia. The production figures also largely represented consumption.

The United States accounted for 57,336,000 barrels, or 53 percent of the above world total, through its large output of natural gasoline, which amounted to 49,896,000 barrels. (Benzol output was 2,440,000 barrels and that of liquid gas, largely propane-butane, was 5,000,000 barrels.)

R. V. Whetsel

Stimulated by war, Germany's production of petroleum substitutes, largely from coal, rose in 1939 to 20,000,000 barrels.

Since the war began, substitutes have become increasingly important in meeting Europe's deficiency of petroleum, although synthetic plants and oil storage have been systematically bombed.

Natural gasoline in many cases should be considered a petroleum product rather than a substitute. The United States produces nearly 80 percent of the world's natural gasoline, and Canada ranks second.

Propane and butane may be liquefied and used as motor fuel or as domestic fuel, and liquid gas is obtained also as a by-product in manufacture of synthetic gasoline from coal. The United States produces 5,000,000 barrels annually of liquid gas, most of which would substitute for motor fuel. Methane from wells in Italy is used as fuel in motor vehicles.

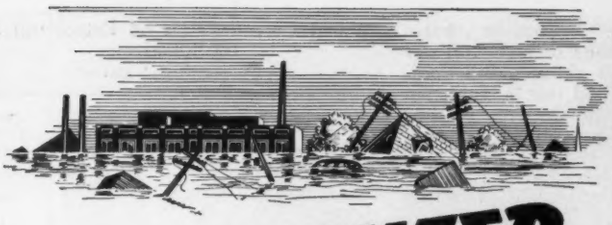
Gasoline and benzol are the principal

World Production of Petroleum Substitutes in 1939

COUNTRY	MOTOR FUEL, Barrels										Shale Oil and Miscellaneous Products, Barrels	Total U. S. Barrels
	GASOLINE			Benzol	Alcohol	Liquid Gas	Methane*	Manufactured Gas*	Producer Gas*	Total Motor Fuel		
	Natural	From Coal	From Shale Oil									
United States	49,896,000			2,440,000		†5,000,000				57,336,000		57,336,000
Germany		11,500,000		4,300,000	1,300,000	1,400,000		120,000	40,000	18,660,000	1,500,000	20,160,000
United Kingdom		3,200,000	230,000	2,000,000	250,000			25,000	25,000	5,730,000	600,000	6,330,000
Japan		1,600,000			2,396,000					3,996,000		3,996,000
France		900,000	13,000	600,000	1,600,000			230,000	80,000	3,423,000	75,000	3,498,000
Canada	3,000,000									3,000,000		3,000,000
Netherlands E. Indies	2,000,000									2,000,000		2,000,000
Estonia			220,000							220,000	1,080,000	1,300,000
Russia	1,000,000		40,000							1,040,000	175,000	1,215,000
Peru	1,100,000									1,100,000		1,100,000
Mexico	1,000,000									1,000,000		1,000,000
Iran	1,000,000									1,000,000		1,000,000
Venezuela	1,000,000									1,000,000		1,000,000
Rumania	800,000									800,000		800,000
Colombia	700,000									700,000		700,000
Italy	60,000				350,000		71,000	110,000	40,000	631,000		631,000
Australia			1,200		450,000					451,200	5,000	456,200
Argentina	450,000									450,000		450,000
Belgium				300,000						300,000		300,000
Philippine Islands					300,000					300,000		300,000
Sweden				5,000	250,000				20,000	275,000		275,000
Trinidad	250,000									250,000		250,000
New Zealand					180,000					180,000		180,000
British Borneo	160,000									160,000		160,000
Egypt	160,000									160,000		160,000
British India	150,000									150,000		150,000
Poland					100,000					100,000		100,000
Ecuador	80,000									80,000		80,000
Hungary					80,000					80,000		80,000
Spain			9,500							9,500	41,000	50,500
Lithuania					50,000					50,000		50,000
Chile					13,000					13,000		13,000
	62,806,000	17,200,000	513,700	9,645,000	7,319,000	6,400,000	71,000	485,000	205,000	104,644,700	3,476,000	108,120,700

* Used as gases for transportation motor fuels.

† Largely propane-butane.



UNDER WATER FOR DAYS—

THIS K&M INSULATION IS AS EFFICIENT AS EVER

Showing the mud-stained K&M insulation, immediately after the flood had subsided. Not a pretty picture in itself, but one which testifies to the money-saving durability of this K&M insulation—a feature of vital interest to users. This is an actual case, from the Keasbey & Mattison files. Material was applied by Louisville Insulating & Supply Co., approved K&M Distributor.

Seven feet of muddy water filled this boiler room when flood waters engulfed it. Not for days did the flood subside . . . but when it did, the mud-stained Keasbey & Mattison "Featherweight" 85% Magnesia which insulated this plant's steam boilers, after being washed and dried, picked up the job of saving heat and fuel just as if nothing had happened!

60,000 square feet of K&M "Featherweight," two inches thick, had helped to keep these boilers at their normal high operating temperature during previous years. Following the flood, the boiler operating efficiency was as high as ever. And when new, larger boilers were recently installed, it is not surprising that K&M "Featherweight" 85% Magnesia once again was the insulation selected.

This incident shows that K&M "Featherweight" 85% Magnesia is not only one of the most efficient heat insulators ever developed for temperatures up to 600° F., but that it is also one of the most durable. Like all K&M asbestos and magnesia products, it is the result of nearly seventy years' specialized experience in building superior insulation materials for American industry.

Keasbey & Mattison engineers, working with K&M Distributors strategically located throughout the country, can point the way to real savings in your plant, too. Write Dept. 11 for full details.

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petroleum substitutes made from coal. Kerosene, diesel oil, fuel oils, and limited amounts of lubricants also are commercially produced from coal.

Manufactured gas from coal is used as motor fuel in Germany, England, and Italy, being compressed into lightweight cylinders at 4000 pounds per square inch pressure and carried on automobiles and trucks. Producer gas from wood also is used as motor fuel in Europe.

The world's production in 1939 of petroleum substitutes from coal amounted to about 28,730,000 barrels, with Germany accounting for nearly 60 percent of the total.

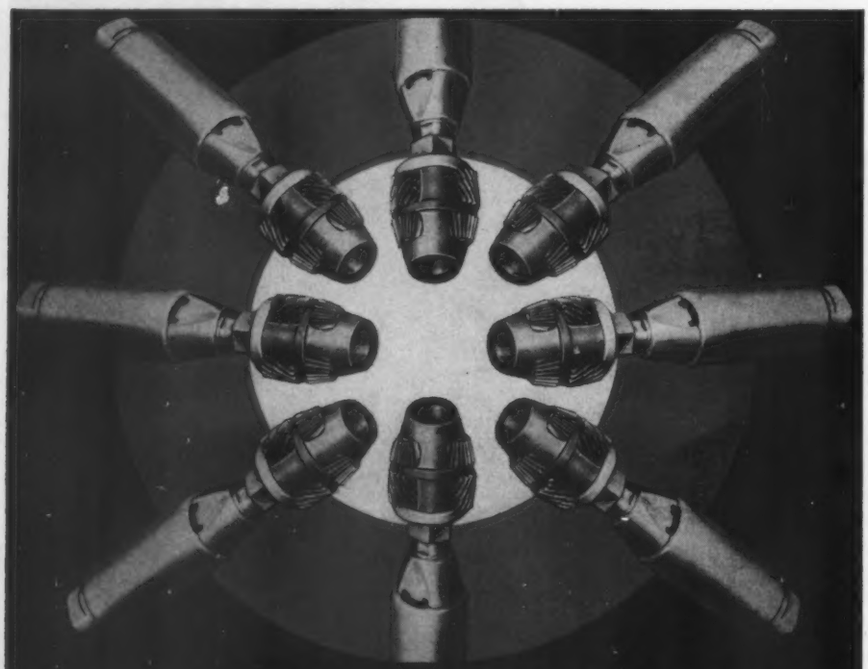
Shale oil is obtained commercially by grinding shales and retorting them in a manner similar to low-temperature carbonization of coal. Australian shales yield about 100 gallons of shale oil per ton, the Estonian 50 gallons, the Scottish and French 25, and the Manchurian shales about 14 gallons. The world's production in 1939 of petroleum substitutes from oil shales aggregated about 2,490,000 barrels, Estonia having been the leading producer, with output of 1,300,000 barrels.

Synthetic alcohol, particularly as methanol, has come into extensive use in Europe for blending with motor fuel. Ethyl alcohol is made largely from potatoes, sugar beets, molasses, rye, and other vegetable substances. The world's production in 1939 of alcohol used as motor fuel was about 7,320,000 barrels, and the United Kingdom, with output of nearly 2,400,000 barrels, was the leading producer.

World Consumption of Petroleum and Its Substitutes
(Thousands of Barrels)

	1938 Total	1939 Total
United States	1,140,923	1,236,076*
Russia	164,500	170,600
United Kingdom	90,300	88,200
Germany	56,700	54,000
Canada	45,900	49,200
France	49,100	44,200
Argentina	29,500	30,950
Japan	25,000	25,400
Italy	20,500	21,800
Netherlands West Indies	20,650	19,850
Mexico	18,000	18,600
Australia	16,250	16,280
British India (Ex. Bruma)	15,450	15,700
Rumania	12,780	14,400
Netherlands	10,950	11,800
Netherlands East Indies	11,350	11,450
Iran	10,600	11,100
Sweden	10,050	10,950
Union of South Africa	8,270	10,300
Venezuela	8,925	9,530
Brazil	8,820	9,300
Denmark	6,680	6,930
Belgium	6,395	6,750
Egypt	5,650	6,300
French West Africa	5,390	5,770
Cuba	4,800	5,400
Chile	5,030	5,260
Spain	4,650	5,260
Norway	4,580	5,250
New Zealand	5,370	5,220
Aden	4,937	5,137
Trinidad	4,720	5,110
British Malay	4,250	4,900
China	4,600	4,350
Philippine Islands	3,700	4,250
Iraq	3,840	4,160
Hawaiian Islands	4,000	4,140
Colombia	2,975	3,377
Switzerland	3,250	3,310
Poland	3,050	.....
Uruguay	3,030	3,270
Ceylon	3,380	3,210
Panama Canal Zone	3,000	3,130
Greece	2,650	2,900
Finland	2,100	2,440
Irish Free State	2,350	2,430
Czechoslovakia	2,220	.....
Peru	2,570	2,380
Hungary	1,930	2,370
Algeria	1,855	1,990
Puerto Rico	1,800	1,880
Palestine	1,600	1,770
Jamaica	1,620	1,740
Burma	1,550	1,600
Portugal	1,515	1,560
French Morocco	1,420	1,540
Hong Kong	1,240	1,380
Turkey	1,280	1,330
Yugoslavia	1,090	1,090
Kenya and Uganda Inc, Zanzibar	980	1,005
Miscellaneous	16,362	16,982
	1,917,927	2,026,557

* Includes 5,000,000 barrels of Propane-Butane.



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Write for the name of our representative nearest to you or send for a copy of the thirty-six page catalog which fully describes and illustrates us and the complete line of Wilson tube cleaning equipment.

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Dangers of Underestimating Germany's Self-Sufficiency in Liquid Fuel

By B. Orchard Lisle,
Consulting Petroleum Technologist, New York, New York

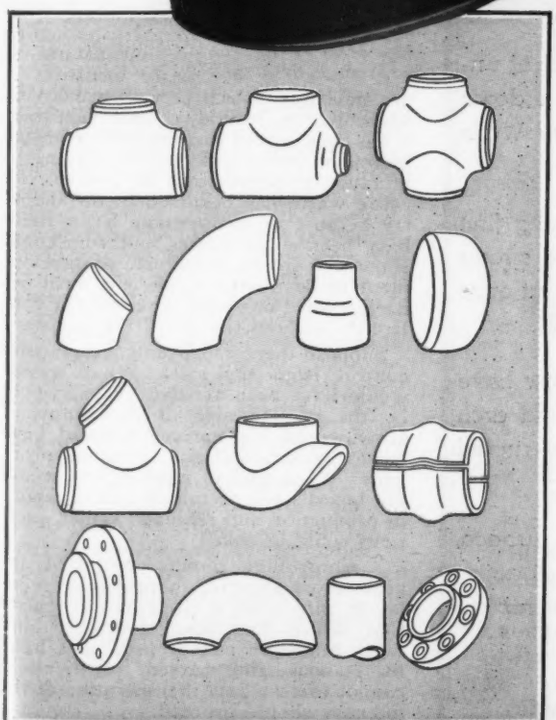
Although it is beginning to be recognized that Germany is not so badly lacking in liquid fuel supplies as had formerly been thought, there is still a tendency to underestimate that country's resources. Efforts have been made, in spite of censorship and propaganda, to obtain reliable estimates on the quantity and quality of the potential Nazi productive capacity.

Germany is producing substitutes for petroleum oils by various synthetic processes, the leading ones being: hydrogenation of coals, lignite and tar oils; the Fischer-Tropsch synthesis of

MIDWEST REDUCING Butt-Welding Elbows

The Reducing Butt-Welding Elbow has recently been developed by Midwest to meet a need that has existed for a long time. In a pipe line where it is necessary to change both direction and pipe size, this reducing elbow takes the place of two welding fittings: (1) a straight elbow and (2) a reducer. The result is the elimination of one or two welds, saving in erection time and expense, and an improved appearance.

For complete information regarding Midwest Reducing Elbows, see the new Midwest Welding Fittings Bulletin WF-41 (now available from nearest office or distributor).



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(See New Bulletin WF-41)

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liquid products from gases; the Fischer-Pichler Mittelbruck, medium-pressure synthetic process; the Pott-Broche process of obtaining liquids from coal by a combination of solvent extraction and hydrogenation; the Uhde process, somewhat similar to the Pott-Broche method; and numerous variations of the coal carbonization process. Also, Germany is making up for deficiencies in petroleum supplies by the use of liquefied gases as motor fuel, the use of alcohol, "gasogene" generation of fuel gas by burning wood, coke, etc.

Germany has had her annual production of domestic petroleum increased materially by discovery of a new field shortly before the outbreak of the war. Furthermore, the German-occupied countries of Poland, Austria, Czechoslovakia and France are yielding increasing quantities of oil under German control and exploitation. Germany may be securing at least half of Hungary's annual production of about 1,700,000 barrels, and is likely to obtain all the 21,000,000 barrels or more of exportable petroleum from Rumania. From Russia and Sovietized Poland, Germany has been getting unknown quantities of oil.

Altogether, it is concluded that during 1941 Germany may be provided with a total of about 46,188,000 barrels of "ersatz" materials, some 8,800,000 barrels of crude from oil fields in Greater Germany and officially occupied countries and an additional 32,350,000 barrels from countries within the Axis or under its domination. The grand total is 87,338,000 barrels. This compares with an estimated grand total of 56,648,000 barrels in 1940.

With respect to the quality of gasoline made by the hydrogenation process, it is possible to secure a fuel with a C.F.R. octane number of 70 or higher. Richer materials permit manufacture of gasoline of 85-octane number, and with the use of tetraethyl lead the gasoline may have its octane number raised to 92 or 95. British tests of fuels taken from captured German planes showed that the planes had been operating on gasoline of 92-octane number.

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TOUGH
CHEAP

Engineered from the ground up—stripped of unnecessary material and weight—trimmed down to a slim thinness—THINSULITE Furnace Walls are really streamlined.

A complete integral construction combining first grade refractory, ample insulation, and a strong supporting frame, provides a wall that is at once permanent, flexible and heat and air tight.

At the price of ordinary brick you can now have a modern sectionally supported wall—and arch—one that gives you assurance of uninterrupted operation and long life.

THINSULITE is suitable for use in any furnace, on all areas where abrasion, spalling or slagging are not likely. Detred construction is recommended for the heavy-duty areas.

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See the heat transfer curves shown in the THINSULITE Catalog sent on request.

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The Validity of Competition in a Natural Resource Industry

By John D. Gill,

The Atlantic Refining Company, Philadelphia, Pennsylvania

The question before us is whether the principle and practice of competition can be abandoned in favor of the practice of some other principle without injury to democracy and our economic development. The author's answer is "No." Encroachments on individual freedom in a competitive system tends to put a brake on material progress and defeats the purpose of the abrogation of rights.

J. D. Gill

The driving, progressive conduct of operators in competitive, non-natural-resource industries is the same force which provides validity to competition in natural-resource industries. It has been argued that competition in the petroleum industry should be eliminated in favor of some form of control because waste has occurred in the industry because of competition. True, there have been some wastes, but who could show that for an equal rate of development these wastes would not have occurred had there been government control throughout the life of the industry?

Suppose there had been governmental control from the start. What wastes would have been avoided? What would be the present size of the industry? How would a government board have faced the technical and economic problems? When and to what extent would the board have permitted new methods in production and refining? Other questions could be asked.

A controlling bureau or board appears most effective in providing regulation only when it attempts to regulate that which has been developed and when hindsight can be used as a basis for standardizing current practices. It cannot foresee how the operation of the industry should proceed.

The persistence of demands for noncompetition and government control thrives on fragmentary and often illogical concepts. For one thing, the degree to which physical waste has occurred has been magnified. Also, extreme conservationists fail to consider the trend of developments more and more toward the production of materials from virtually illimitable sources, such as the various synthetic methods. Finally, the

relation between the oil industry and the entire economy has been almost completely ignored. The notable growth of the American economy has been made possible by the rapid exploitation of petroleum.

Some Factors in the Economics of Recycling

By Emby Kaye

Distillate Engineering and Processes Company, Tulsa, Oklahoma

Recycling is the generic term describing the recently developed process by which a condensate is separated from a gas-distillate gas at high pressure and the residual gas is returned to the subterranean reservoir. Before the development of recycling, a great many gas-distillate fields in Louisiana and Texas provided no income to their owners. When gas was taken from the reservoirs there were irretrievable losses of condensate from the formation. The introduction of the recycling process permits the conditioning of gas-distillate fields for the sale of dry gas without waste.

Emby Kaye

The study of a field for possible exploitation involves the evaluation of a number of economic factors, among them being (1) an estimate of the distillate reserves in place, (2) an estimate of the distillate that can be brought to the surface, (3) available market, (4) costs. Estimating the reserves in place has to be done on the basis of acreage, sand thickness, reservoir pressure, reservoir temperature, porosity and connate water. There are difficulties and uncertainties involved in determining what portion of the wet gas reserves may be brought to the surface for processing before dilution or mixing with dry gas makes the operation uneconomical. A description is given of a sampling device for taking a representative sample of gas from condensate wells flowing under actual conditions.

The principal methods for recovery of distillate from wet gas are: (1) mechanical refrigeration and retrograde condensation, (2) regenerative cooling and retrograde condensation, (3) absorption processes operating at high pressure. In some plants combinations of the above methods are used. The character of the gas, or the nature of the desired product, or both, may often control the choice of method.

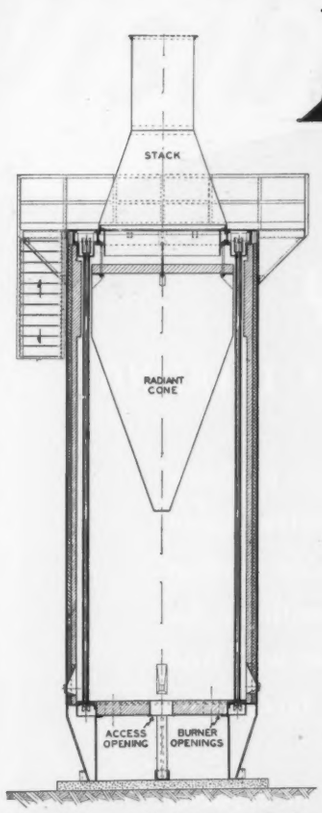
The size of the plant to be built depends on numerous conditions, the principal being (1) the extent of reserves, (2) the market for gas, (3) the market for condensate, (4) cost of production. If reserves are very large, a size of plant that will cost the least per unit of capacity and will be lowest in cost of production should be considered. The smallest plant of economic size must absorb the cost of the camp, development of the camp site, loading facilities, power plant and lighting system, instrumentation and controls, buildings, water supply, sanitation, fencing, laboratory, storage space, repair shop, Ethyl blending plant (if motor fuel is to be produced at the plant), gas gathering system and other items. As little as $75,000 and as much as $150,000 may be spent for the above facilities for a plant with a capacity of 25 million cubic feet, which is considered to be as small as is feasible for processing gas of approximately 1 gallon of condensate per 1000 cubic feet. Plants built to date have cost from $8 to $13 per 1000 cubic feet or from $8 to $13 per gallon of condensate. Ordinarily, $11 per 1000 cubic feet should, with wells of average size, cover the usual costs of an efficient plant of 50 million cubic feet capacity and designed for a field having a reservoir pressure of 3000 pounds. A plant should be projected to pay out the investment in from 2½ to 3½ years and allow at least an additional five years of profitable operation. Where there are very large reserves, longer payout periods may be permissible.

Operating costs per unit of capacity depend on the reservoir pressure, condensate content of the gas, extraction efficiency, gas capacity of the wells and the nature of the condensate. Costs of production per gallon of condensate are affected by substantially the same factors, particularly the richness of the gas and the percentage of production or value thereof paid to the producer of the gas or allocated to the lease from which the gas is produced. Direct operating costs per gallon, exclusive of the raw material, are comparable to those of natural gasoline plants of equal capacity. Depreciation should be put on a short-term basis because of uncertainty regarding the life of the project. The following cost data

NEW

ISO-FLOW FURNACE

PREFABRICATED



The design and features of the ISO-FLOW FURNACE are the subject matter of application for U. S. Letters Patent.

Designed and built for all phases of general refinery service including distillation, cracking, high temperature gas pyrolysis and gas plants. Also as a pipe line heater and steam superheater. THE ISO-FLOW FURNACE offers for the first time a completely prefabricated unit of large size with a minimum of installation labor and a low capital investment.

Illustrated is an installation at a Texas Recycling Plant handling 10,000 bbl. per day. This unit went on stream 81 days after receipt of order and immediately operated at 25% over design capacity. FIVE completely shop assembled ISO-FLOW FURNACES have just been shipped for installation in the Far East.

PETRO-CHEM DEVELOPMENT CO.

INCORPORATED

120 EAST 41ST STREET, NEW YORK, N. Y.

are shown for plants of different capacities:

Gas capacity, million Cubic feet	25	40	60[a]	60
Assumed value of condensate, dols./gal..	0.025	0.025	0.025	0.025
Operating cost ...	0.0054	0.0037	0.0042	0.0031
Depreciation (5 yrs. to 10% salvage)	0.0067	0.0048	0.0053	0.0045
Cost of gas	0.0125	0.0125	0.0125	0.0125
$Total cost gallon..	0.0246	0.0210	0.0220	0.0201

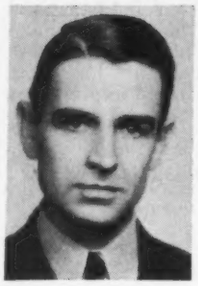
[a] This plant has facilities for cutting several end products; hence higher costs.

Late in 1940, 24 recycling plants were in operation, 5 were under construction and 6 were being planned. In 1941 the daily production of condensate will be a little more than 3 percent of the crude oil production of Louisiana and Texas. With a few expections the plants are in fields discovered more than two years ago.

Factors Influencing Wet Gas Recovery by Recycling

By Judson S. Swearingen,
Associate Professor of Chemical Engineering,
University of Texas, Austin, Texas

In the production of condensate wells by the conventional recycling method the course taken by the dry injected gas is highly important. This fact was not given sufficient attention in the early days of recycling, when the return of gas into the sand was considered largely as a method of gas disposal. Opinions as to the course of the gas ranged from the view that the gas diffused out into the reservoir to the supposition that it channeled directly to the producing well. In 1939 a study was



J. S. Swearingen

made of the patterns formed by the injected dry gas for fields of uniform thickness and uniform porosity and permeability, but available data were meager. A study based on a comparison of actual field data with experimental results has been made.

The datum that is of final interest is the plot of richness against volume circulated in a two-dimensional field. This richness curve is shown to be the differential, or slope, of the total recovery curve. An analysis was made of a one-dimensional path, specifically a narrow tube packed with 30-40 mesh sand. The voids in the tube were filled with dilute sodium chloride solution, and the solution was then displaced with distilled water, which was used instead of gas. From samples taken for chloride determinations the curve of richness at the outlet end of the tube versus volume put through was determined. If displacement were perfect, the salt concentration would drop instantly from a constant value to zero when the pure water reached the outlet end of the tube. Actually, about 95 percent of the salt solution was displaced by the time a volume of water equal to the volume of the voids had been injected. The size of the sand grains is an important factor in the degree to which mixing occurs. Fine sand effects considerably less mixing than does coarse sand for the same distance traversed.

The fraction displaced in a two-dimensional path before the richness falls below a given point because of dilution is of practical concern. A two-dimensional field consists of many single-dimensional paths, some of which go almost directly from the injection to the producing well and others of which follow long, circuitous routes. Due to the differences in lengths of the paths, the streams from the shorter paths become quite lean before the streams from longer paths may have undergone changes. An integration of the richness from all the paths gives the decrease in richness with volume circulated. Inasmuch as some paths are still rich, some are lean and still others are in process of becoming lean, the total drop in richness with volume circulated approaches the result obtainable if displacement were perfect.

It has been suggested by many investigators that a highly permeable stratum through the middle of a producing horizon would permit the dry gas in a recycling operation to pass quickly from the injection well to the producing well and practically dry it up, while at the same time high percentages of rich gas still remain in less permeable layers. The important and hitherto neglected factor in flow through sand is the component of the flow at right angles to the direction of the flow even though the flow through the sand is viscous. This transverse movement is recognized only for turbulent flow through conduits. The extent of the transverse movement of fluid was revealed by experiments with an apparatus introducing dye into one side of a sand-packed tube while

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water was flowing through the sand. The transverse fraction of movement varied from 1/35 for very slow (viscous) flow to 1/15 for a slightly turbulent rate of flow. Fluid layers having different degrees of richness are brought together between grains of sand, and the distance through which material must go by diffusion as well as the amount transferred are both decreased. Experimental studies show the effects of non-uniform permeability.

A fairly accurate comparison between field data and predicted results can now be made. It is evident that a reasonably accurate estimate of the recoverable reserve of wet gas may be made by the use of experimental data if the data are used in conjunction with a correction factor of 0.8 or 0.9 which varies with relative well positions and the uniformity of permeability of the sand.

The Density of Natural Gases

By Marshall B. Standing *and* Donald L. Katz

University of Michigan, Ann Arbor, Michigan

Data on the densities of natural gases are necessary in many calculations in oil production and utilization. Gas reserves, reservoir pressure changes, gradients in gas wells, gas metering, pipe-line flow and gas compression are typical problems requiring knowledge of the density of the gases involved. Recent discoveries of pools having pressures up to 7500 pounds per square inch, and installation of pressure maintenance and recycling plants have increased the need for gas density data at high pressures.

D. L. Katz

The accepted method of calculating the density or specific volume of natural gases is the use of the ideal gas law corrected by a compressibility factor. The method proposed by Kay, of correlating compressibility factors for gas mixtures on pseudo-critical properties, appears satisfactory for natural gases. The compressibility factor for methane has been shown to deviate systematically from the behavior of natural gases, and a chart giving these corrected factors is available.

This paper presents the data on densities of 16 saturated gases in equilibrium with crude oils. The relationships developed to compute the density of gases to high pressure have been modified and enlarged. A simplified method of obtaining gas density is presented in the form of charts which apply for specific groups of gases. In the process of obtaining equilibrium data on mixtures of natural gas and crude oils, the density and analyses of the saturated vapor phases were obtained. These data were in the range of 35 to 250° F. and 1000 to 8220 pounds per square inch.

The recent density data of Sage and Reamer on the separator gas from the Rio Bravo field are compared with the computed densities and compressibility factors. The agreement between computed and experimental results should be representative of gases of that type, since the data were not used in any of the correlations.

A set of charts giving the density as a function of gas gravity, temperature and pressure could be prepared for any series of gases which have a smooth relationship between gas gravity and pseudo-critical conditions. Gases from a common source such as the data of this paper, or gases of similar composition may be expected to have such a relationship.

Beman Elected

John Beman has been elected president of the Pennzoil Company of California. He succeeds Norman Day, who died in February.

Fire Protection Handbook Revised

Several chapters of the ninth edition, Crosby - Fiske - Forster Handbook of Fire Protection, Robert S. Moulton editor, are of interest to both refiner and natural gasoline manufacturer. They deal with heat appliance, flammable liquids, gases and internal combustion engines, hazardous chemicals and explosives, and special extinguishing systems.

Many of these chapters have undergone extensive revision since the last previous edition was published.

The book is available through the National Fire Protection Association, 60 Batterymarch Street, Boston, at $4.50.

Visibility AT A GLANCE

It doesn't take a second glance to see the liquid level indicated in the illustration at the right. And that is exactly the way a "Pyrex" Broad Red Line Gauge Glass looks from directly in front. The liquid level always stands out clearly in a "Pyrex" Broad Red Line Gauge Glass.

The broad, transparent red line is fused permanently into the wall of the gauge glass. It won't wash off or wear off. And because the gauge glass is made of "Pyrex" brand Glass, it will stand up against thermal shock and mechanical shock and will maintain its transparency longer. Stocked by leading mill and steam supply houses.

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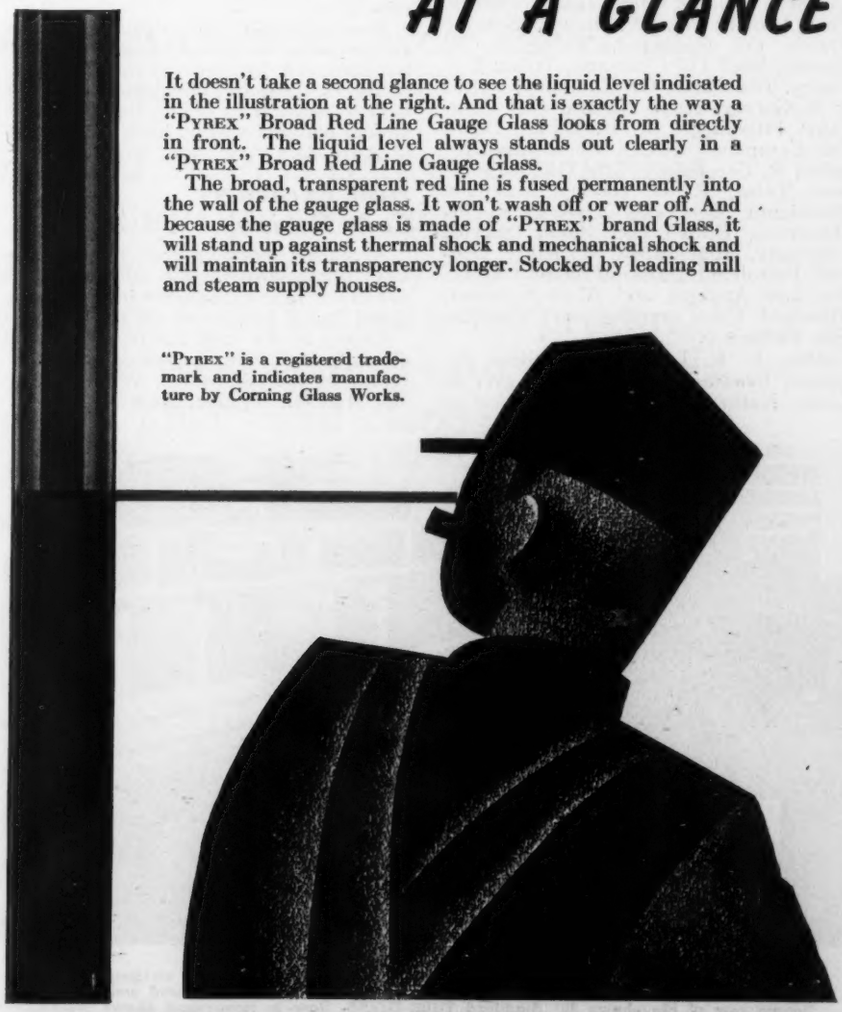


Corning Glass Works, Corning, New York

Pyrex Gauge Glasses

F. E. Rice Heads API Measurement Committee

F. E. Rice, vice president of Phillips Petroleum Company, Bartlesville, has been named chairman of the Central Committee on Measurement, Sampling and Testing of Natural Gas and Natural Gasoline, Division of Production, American Petroleum Institute. Rice entered the petroleum industry in 1917 as engineer for Frank P. Peterson Company. He joined Phillips Petroleum Company in a similar capacity. Successively, he was superintendent of the natural gasoline department, vice president in charge of manufacturing, vice president in charge of natural gasoline and natural gas, and was named a director of the company in 1938.

F. E. Rice

Members of the committee are George P. Bunn, Phillips Petroleum Company, vice chairman; C. A. Young, secretary, and M. J. Adams, The Texas Company, Fort Worth; W. W. Baker, Sinclair Prairie Oil Company, Tulsa; B. R. Carney, Shell Oil Company, Tulsa; J. J. Conry, The Carter Oil Company, Tulsa; J. B. Garner, Hope Natural Gas Company, Pittsburgh; R. D. Gibbs, Union Oil Company of California, Los Angeles; R. Greenslade, Gulf Oil Corporation, Tulsa; R. D. Hanley, Magnolia Petroleum Company, Dallas; R. H. Hargrove, United Gas Public Service Company, Houston; M. W. Kibre, General Petroleum Corporation of California, Los Angeles, and Alois Kremser, Standard Oil Company of California, San Francisco.

Also, E. R. Lederer, consulting engineer, Bradford, Pennsylvania; W. F. Lowe, Natural Gasoline Association of America, Tulsa; H. M. Manley, Barnsdall Oil Company, Tulsa; W. H. Meier, The Atlantic Refining Company, Dallas; Ray E. Miller, Hanlon-Buchanan, Inc., Tulsa; William Moeller, Jr., Southern California Gas Company, Los Angeles; G. G. Oberfell, Phillips Petroleum Company, Bartlesville; E. L. Peck, Cities Service Oil Company, Bartlesville; E. F. Schmidt, Lone Star Gas Company, Dallas; F. M. Seibert, Gulf Oil Corporation, Houston; J. O. Sue, Humble Oil & Refining Company Houston; M. B. Sweeney, Sun Oil Company, Dallas; M. E. Wagner, The Ohio Oil Company, Tulsa; P. G. Weidner, Stanolind Oil & Gas Company, Tulsa, and Frank Wells, Pacific Gas & Electric Company, San Francisco.

Safety Problems on New York Program

Specific safety problems of the petroleum industry will be a part of the program of the twelfth annual Safety Convention and Exposition of the Greater New York Safety Council, Hotel Pennsylvania, New York, April 22-25. A full program is planned on the subject, to include anticipation of personnel safety, storage, refining and preservation of man power.

More than 600 delegates and visitors are expected to attend. Equipment will be displayed by more than 100 manufacturers. Special luncheons will be held by several of the sections, and the annual banquet will be held the evening of April 24.

Heat Exchanger Code Revised

A revised tentative code for mechanical design, construction and inspection of tubular heat exchangers has been prepared by a committee of refiners.

Copies of the code can be obtained at 40 cents each from the office of the secretary of the committee, W. J. Parker, 366 Madison Avenue, New York.

Harts Promoted in Warren Organization

H. W. Harts was elected a vice president of Warren Petroleum Corporation at the meeting of directors in January. He will be in charge of manufacturing. Since 1935, he has been superintendent of natural gasoline plants.

Harts is a graduate of the University of Illinois. He came into the oil industry in 1921 as a surveyor for Amerada Petroleum Corporation, and in 1925, he took charge of construction of natural gasoline plants for that company.

H. W. Harts

When Warren Petroleum Corporation took over natural gasoline plants of Amerada Petroleum Corporation in 1935, Harts became assistant general manager of Natural Gasoline Corporation, the manufacturing subsidiary set up by the Warren organization. A few months later he was promoted to general superintendent.

Harts has served as chairman of the technical committee of the Natural Gasoline Association of America. He was general chairman of its program committee for the annual meeting in 1941.

Revised Control Bill Promised

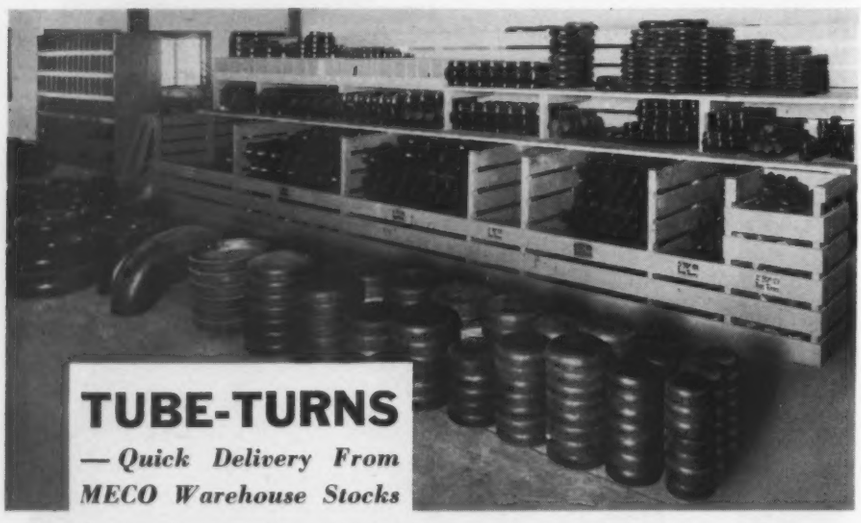
Department of the Interior officials last month were reported working on a new oil control bill, to be suggested to Congress as a substitute for the Cole bill which was before the House Interstate and Foreign Commerce Committee throughout the last Congress.

Details of the projected measure were closely guarded, but there were suggestions that it will be more or less along the lines of the Cole bill but in such form as to allay the opposition of the oil states having control laws in operation.

Like many measures which have been proposed in the past six months, national defense will be invoked as the objective to be sought, and there may be some exploratory discussion of that angle at brief hearings which the House committee is expected to hold this month, at which, however, the pipe line situation is now seen as the major subject of consideration.

While Secretary of the Interior Harold L. Ickes continues to maintain that there should be closer cooperation between the federal and state governments and the oil industry toward elimination of waste, defense officials have given no indication that they are interested, although late last year they were represented as apprehensive over the ability of the oil industry to meet the petroleum needs of the defense program. Due to their lack of interest, the oil group of the House committee abandoned plans for hearings on that matter.

Meanwhile, hearings before the Temporary National Economic Committee on suggestions for legislation to be incorporated in its report closed without any reference having been made to oil, although that industry was one of a



Pictured above is a part of our TUBE-TURN Stocks. Top row of bin shows welding reducers, tees and 180° TUBE-TURNS. Middle row of bin shows 45° TUBE-TURNS and welding tees. Bottom row of bin shows 90° Standard TUBE-TURNS. Row in foreground shows welding heads and 180° TUBE-TURNS. Standard, extra heavy and double extra heavy patterns are available for quick delivery from our large, complete Houston stocks.

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number thoroughly investigated by the committee in 1939-40.

Appearing before the committee to submit the recommendations of the Department of Justice, Assistant Attorney General Thurman Arnold last month failed to make any mention whatever of oil, explaining privately that he saw no need for legislation affecting the industry and expressing the belief that whatever monopolistic practices existed would be dealt with by the suit now pending in the District of Columbia federal court.

Officials of the Securities and Exchange Commission appeared before the committee and also failed to offer any suggestions for the control of the oil industry.

Representatives of independent marketers are attempting to secure hearings on the Gillette divorce bills, but have been advised that the Senate Judiciary Committee will not consider any investigations until after the lend-lease legislation is disposed of. While it is expected that the committee will grant hearings, it is not believed that the legislation will make much progress this year in the face of the failure of the TNEC to make recommendations, and also the opposition of the National Defense Advisory Commission voiced last year, to any action which might lead to disorganization of the industry during the present emergency, with particular reference to divorce.

The commission's views were expressed during consideration by the Department of Justice of the oil suit which it later filed, and led to the dropping of a demand for disintegration in that case.

Initiation of the Navy's program for the development of underground storage facilities for oil was provided for by a $5,000,000 fund included in a supplemental Army-Navy supply bill passed by the House and sent to the Senate.

The fund was given the approval of the House appropriations committee after Navy department officials had warned this was but a small part of the construction planned to enable the storage of all fuel underground.

Appearing before the committee during hearings on the bill, Rear Admiral Ben Moreell, chief of the Bureau of Yards and Docks, explained that the Navy has set up a program for fuel storage underground for gasoline, fuel oil and Diesel oil, throughout most of the continental stations, and for the noncontinental stations. At present, he pointed out, all of the Navy's fuel with the exception of aviation gasoline is above ground at Panama, and construction is under way to provide extensive underground storage at Pearl Harbor and Puget Sound. All of the noncontinental air stations are equipped with underground gasoline storage.

Asked by Representative Louis Ludlow as to the depth of the underground storage, Admiral Moreell said "the fuel-oil storage at Pearl Harbor will be in vertical tunnels about 300 feet high and about 100 feet in diameter. In some places we cannot go too far underground because of water conditions. That depends on the locality.

"This is a small part of the project we have for putting all fuel underground," he added.

Octane Rating Still Upward

Increase in the octane number of all grades of gasoline for 1940 in comparison with 1939 is one of the trends shown in the Cooperative Fuel Research Motor Gasoline Survey, a study made by the Cooperative Fuel Research Committee and the United States Bureau of Mines. On comparisons between findings of 1939 and 1940, the report gives this summary:

"A comparison . . . for the three grades of gasoline shows that the average figure for the octane number for the regular price grade is 2.7 units higher for the summer of 1940 than for the previous summer, the premium grade is 1.1 units higher and the third grade is 0.9 units higher than for the previous summer.

"The average vapor pressure for the regular price gasoline is 0.1 pounds higher; for the premium price grade, 0.2 pounds higher; for the third grade gasoline 0.2 pounds lower than for the summer of 1939.

"The average temperatures in the distillations for the regular, premium-price and the third-grade gasoline are lower than for the summer of 1939 at all points except the initial boiling point of the regular price grade. Taking the 50 percent temperature as an example, a lowering of the 6°, 7° and 5° F. is noted for the regular price, premium price and third grade gasolines, respectively."

The bulletin, R. I. 3550, is available through the United States Bureau of Mines.

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Dennis of Coppus Engineering Named to L. S. U. Faculty

Edwin L. Dennis, chief combustion engineer for Coppus Engineering Corporation, Worcester, Massachusetts, has been named to the faculty of Louisiana State University. Making his headquarters at Baton Rouge, he is continuing his duties with Coppus Engineering Corporation.

E. L. Dennis

Dennis received his B.S. degree from Louisiana State University in 1924. He developed the Coppus-Dennis Fanmix burner, utilizing the kinetic energy of fluid fuels under pressure to maintain constant air-fuel ratios.

California Refineries Elect Officials

R. E. Hines, Caminol Oil Company, Los Angeles, has been elected president of the Independent Refiners Association of California. Other officers are B. E. Devere, El Camino Refining Company and Henry Brown, Operators Oil & Refining Company, vice presidents; A. M. Lockhart, Envoy Petroleum Company, secretary-treasurer.

Directors are J. H. Lewis, Sunset Oil Company; C. B. Limbocker, Hancock Oil Company, and L. F. Frankley, Triangle Oil & Refining Company.

D. B. O'Neill was renamed general manager.

Baker Elected Vice President of Humble

Hines S. Baker, who recently was named head of refining and marketing for Humble Oil & Refining Company, was elected a vice president last month. He has been a director since 1937.

Chemists Select Analytic Methods

The theme of the Division of Petroleum Chemistry, American Chemical Society, has selected "Analytic Methods Used in the Petroleum Industry" for the theme of its part of the program of the national meeting of the society, St. Louis, April 7 to 11.

Priority Program Not to Materially Affect Industry

Extension of the priorities system now gradually being adopted for important materials, under which production for defense is given right-of-way over that for civilian consumption, is not expected materially to interfere with operations in the oil industry, accepted as vital to the rearmament program, it was learned in Washington last week.

Thus far, priorities have been imposed upon only two or three of the more highly important metals and are shortly to be extended to other metals, but eventually it is foreseen that the system will be expanded to take in practically all materials entering into the production of defense needs, particularly those on which imports must be depended upon or of which domestic supplies are limited.

Manufacturers of oil field and refining equipment are said to be apprehensive over the effects of priorities but, while it could not be learned that that question has been under consideration, officials in Washington indicated that while such manufacturers might not get prime priority as producers of national defense equipment, they would be given secondary priority in order that oil production not only may be maintained but that groundwork is laid for any increase which may be necessitated by an emergency.

So far, the only action taken with respect to such equipment has been to place it on the export control list, to prevent shipments to "unfriendly" nations and conserve both the equipment and plans for improvements thereof for our own use.

It is admitted in some circles that the equipment manufacturers may encounter some difficulties in securing particular raw materials, but it was said that problem would be worked out between members of the industry and officials of the Priorities Division of the Office of Production Management, headed by E. R. Stettinius.

The administration still is hopeful that the defense program can be carried out side by side with ordinary civilian operations, having in mind the great desirability of maintaining commercial business so as to cushion the shock and dislocation which will follow the cessation of war production. The chief aim of the priorities system to provide adequate supplies for the defense industries is, if possible, to be attained without

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eliminating civilian production or, at most, to curtailing that which is least essential.

The oil industry is seen in Washington as being in a preferential position because of the importance of the commodity to the national defense and its probably equal importance to production for national defense by other industries, and there appears to be no desire anywhere in the administration to curtail the normal activities of any branch of the industry, without which production for defense would become prohibitively expensive.

It is generally expected, therefore, that any problems affecting the industry under the government's defense program will be quickly ironed out so that nothing may menace the continued flow of an adequate volume of oil.

Ease License Demands on Exports to Great Britain

Restrictions on the export of crude oil, gasoline, tetraethyl lead, lubricating oil and naphtha to Great Britain and Northern Ireland were lifted March 3 by orders of Brigadier General Russell L. Maxwell, administrator of export control, authorizing a general license for the export to those destinations of more than 100 commodities from the export-control list.

Not included in the list, and therefore exportable only under individual license, were refining and other equipment and apparatus, and plans therefor.

Under the orders of the administrator, collectors of customs are authorized to permit any exporter to make shipments of the listed commodities to Great Britain and Northern Ireland without the requirement of an individual license, but instructions were issued that exporters should include on their shipper's export declaration the general license number of the commodity shipped, GEA 2 for crude oil, GEB 2 for gasoline, GEC 2 for tetraethyl lead, GED 2 for lubricating oil, and GEE 2 for naphtha.

Petroleum Coke Added to Export Control List

Extending still further the list of petroleum products exportable only under federal license, President Roosevelt on March 4 ordered the addition of petroleum coke to the list of materials under export control.

The proclamation, effective March 10, adds a number of oils and other products to the restricted list, on the recommendation of Brigadier General Russell L. Maxwell, administrator of export control, that it is necessary in the interest of national defense to control their shipment abroad.

Report on Taxes of Oil Companies Paid in 1938

Petroleum corporations active in 1938 had a gross income for that year of $951,472,000, and a net taxable income of $13,387,000 on which they paid income and excess profits taxes of $10,343,000, it was reported March 6 by the Internal Revenue Bureau.

The exceedingly high apparent rate of tax paid, it was explained, was due to the fact that a large percentage of the 5311 corporations reporting had deficits, thereby reducing the taxable net income for the group as a whole.

The bureau's "balance sheet" covered the petroleum industry in its entiretly and gave no segregated figures for any individual branch, so that no distinction can be drawn between operations of producers, refiners, transporters or marketers.

The analysis showed the 5311 corporations had gross sales of $680,025,000 for 1938 and gross receipts from operations of $213,361,000, in addition to $11,571,000 in rents and royalties, and $17,994,000 in dividends from corporations, of which $126,000 was from foreign corporations.

The deductions of the group included $375,289,000 as cost of goods sold, $111,399,000 as cost of operations, $21,328,000 as compensation of officers, $7,560,000 for rent, $24,365,000 for interest paid, $31,623,000 for taxes other than income and excess profits, $77,770,000 for depreciation, $125,459,000 for depletion and unitemized deductions of $156,503,000, the combined total of all deductions being $936,981,000.

The net profit of the corporations was $14,491,000, but the taxable net income, after deduction of $1,104,000 received in interest on wholly tax-exempt government securities, was $13,387,000. Income taxes paid were $10,211,000, and excess profits taxes $131,000, leaving a net profit, after taxes, of $4,148,000.

The report showed that the corporations reporting paid dividends in 1938 of $96,176,000 in cash and $557,000 in stock.

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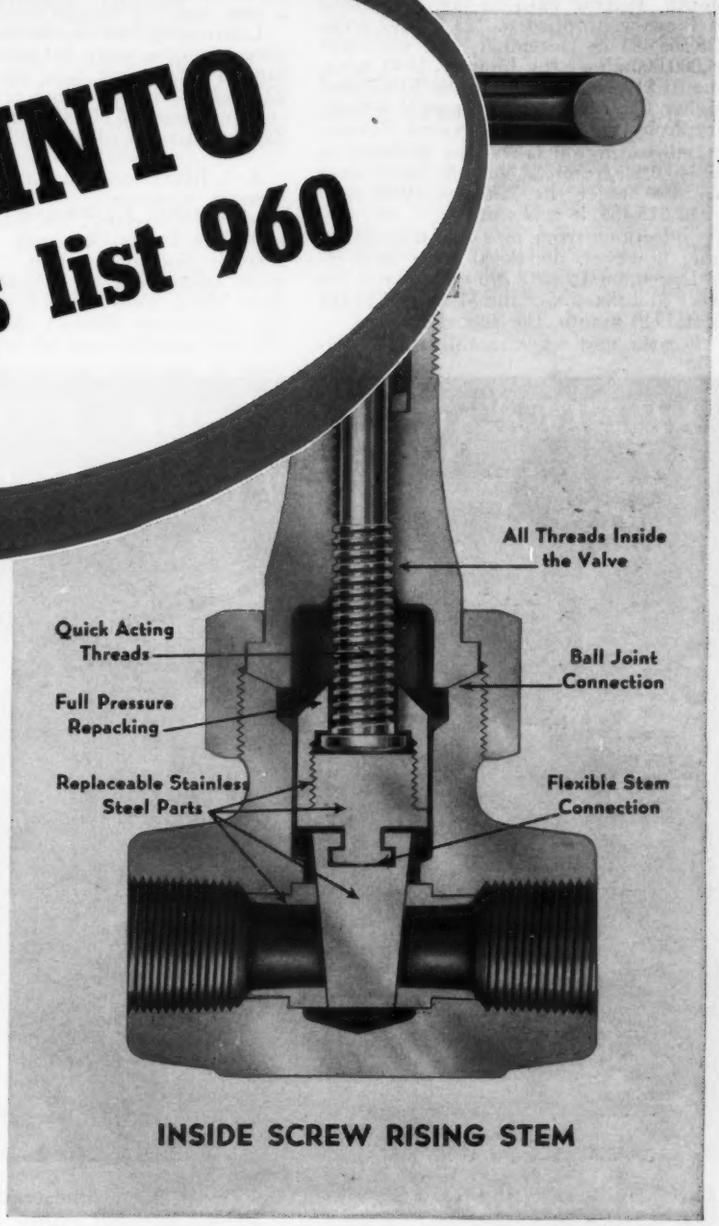

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Federal Gasoline Taxes Down in January

Declining for the second successive month, federal gasoline-tax collections in January dropped to $23,306,897 from $25,566,483 in December, and were but $4,000,000 above the January, 1940, revenue of $19,228,329 despite the 50 percent higher tax rate, it was reported February 20 by the Internal Revenue Bureau.

Lubricating oil taxes also declined, to $2,340,219 from $2,663,018, and were $275,000 under the January, 1940, total of $2,615,468, it was stated.

Collections from pipe-line transportation, however, increased from $853,927 in December to $918,290 in January, but were $130,000 under the $1,049,642 of the first 1940 month, the report showed.

For the first seven months of the current fiscal year, six of them under the 1½-cent tax rate, gasoline tax collections aggregated $197,201,087, an increase of $59,545,660 over the $137,655,427 received in the corresponding period a year ago, the bureau announced.

Lubricating oil collections for the seven months were $21,630,444, against $18,718,231 a year ago, an increase of $2,912,213, and pipe-line transportation revenues were $6,967,472, against $6,592,239, an increase of $375,233.

A. J. Blackwood, Standard Oil Development Company; A. B. Culbertson, Shell Oil Company; Dr. Raymond Haskell, The Texas Company, and George Rounds, Socony-Vacuum Oil Company, were speakers at a national forum in New York, February 17, sponsored by the American Transit Association to discuss gasolines and lubricants.

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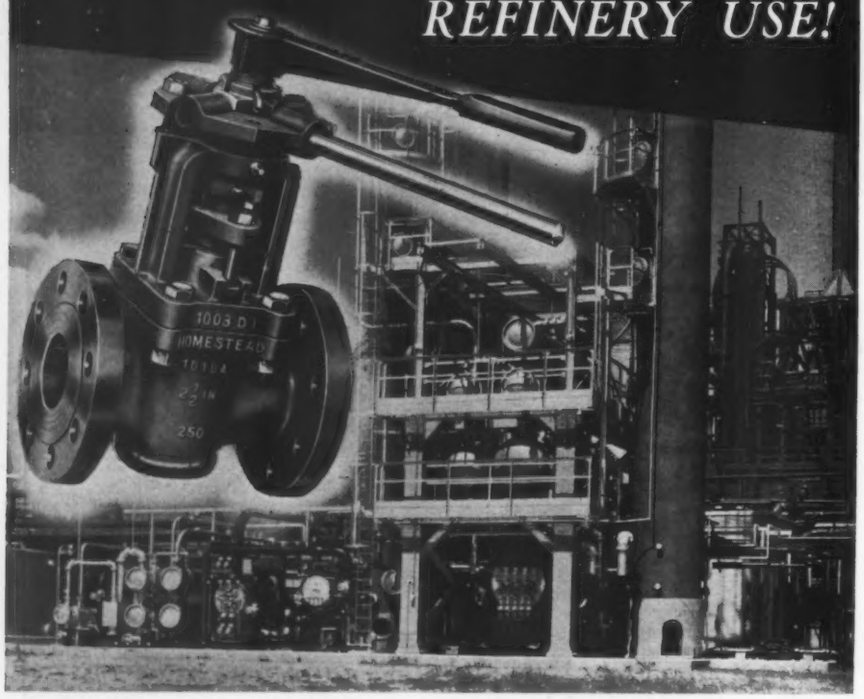

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HOMESTEAD VALVES

Distillate Output Into Pipe Lines

Contracts were signed last month through which 6500 barrels of daily output of Texas cycling plants will have steady market. Gulf Oil Corporation will take the output of the plant of Lone Star Gas Company and Shamrock Oil & Gas Company in Opelika field. A pipe line is being laid to the plant so distillate production can be put into the crude oil stream.

In the Corpus Christi area, Humble Oil & Refining Company will take 2000 barrels of daily output from several plants, to go into crude lines for delivery to refining plants in the Gulf Coast area.

I.P.A.A. Report Shows Industry Can Meet Demands

"Today the industry stands ready to satisfy any demands that may be made of it," is the assertion in a report on "The Petroleum Industry and National Defense," which appears in the March issue of The Independent Monthly, official publication of the Independent Petroleum Association of America.

The report was made by the association's standing committee on balance of supply with demand, whose reports on economic conditions in the industry have been issued each quarter for several years. The committee consists of H. B. Fell, Ardmore, Oklahoma, chairman; Van S. Welch, Artesia, New Mexico, vice chairman; John Trimble, El Dorado, Arkansas; Lawrence Vander Leck, Los Angeles, California; J. A. Aylward, Wichita, Kansas; C. H. Lyons, Shreveport, Louisiana; C. A. Smith, Jr., Grand Rapids, Michigan; H. M. Stalcup, Tulsa, Oklahoma; C. P. McGaha, Wichita Falls, Texas. Minor S. Jameson, Jr., Washington, D. C., statistician for the association, is secretary of the committee.

To discuss the "over-all physical condition and state of preparedness of the industry," the committee has set up an inventory of the petroleum industry of today and of 1918, peak year of the effort of the United States in the World War. The comparisons show, says the report, "the extent to which the industry has changed from a relatively untested and unstable one to a huge, resourceful and dependable segment of our industrial life."

It is shown that the production of crude oil in 1940 was 1,350,000,000 barrels, which was one billion barrels more than the amount produced in the United States in 1918. The number of producing oil wells now is almost double the number in 1918. The price of crude oil, however, is now about half what it was then.

Crude oil is now produced in 23 states, six more than in 1918, and 19 states now produce more than one million barrels annually. In 1918 there were 11 of this size.

Refiners of the United States now can process about three and one half times as much crude oil as they did in 1918; mileage of pipe lines which transport about 75 percent of the crude oil to refineries, is double that of 1918; tanker tonnage is 20 times as great now as then and the 150,000 tank cars used to transport petroleum is more than double the number in use in 1918.

Construction Activity Takes Spurt During February

Construction activity in the refining industry took a spurt last month with announcement of several large projects. First official confirmation of a proposed cycling program for the Katy field near Houston, long rumored, came from Humble Oil & Refining Company, while Louisiana's Cotton Valley cycling project, thus far the world's largest, was being pushed toward completion.

Chalmette Petroleum Installs Copper Sweetening Unit

F. E. Holsten, vice-president of Chalmette Petroleum Corporation, has announced starting of operations on a 4000-barrel Perco copper sweetening unit for its New Orleans refinery. The unit is of the conventional Perco design for refinery light oil treating, and was constructed by L. S. Gregory Company, Tulsa. This unit is processing gasoline made from Gulf Coast crudes.

Building Cycling Plant In Grapeland Field

Hudson Engineering Company is building a $250,000 cycling plant for Geier Brothers and Jackson in the Grapeland, Texas, distillate field. The company has three producing wells, and is drilling a fourth. The plant is located on a 30-acre tract in the D. A. Guice farm.

Approve Plans for South Louisiana Cycling Plant

The way was cleared for construction of a $500,000 cycling plant in the 2000-acre South Jennings field, Jefferson Davis Parish, Louisiana, when Conservation Commissioner B. A. Hardy approved the project submitted by Stanolind Oil & Gas Company. Plans call for cycling gas from the 8600-foot horizon.

Wood River Illinois Plant Nearing Completion

At Hartford, Illinois, Wood River Oil & Refining Company is nearing completion on its 7500-barrel skimming plant, which will include a 2000-barrel cracking unit. The plant will use crude from Southern Illinois fields, brought by tank car and pipe line, and will ship by barge, rail and tank wagon.

Shell Adding Butadiene Plant at Houston

Shell Oil Company has announced the award of a contract for construction of a plant at its Houston refinery for the manufacture of butadiene, basic ingredient of synthetic rubber

Scheduled to be in operation by early summer, the plant will have an annual capacity in excess of 5000 tons. Contract for the plant has been awarded to C. F. Braun Company, Alhambra, California, and construction will start immediately.

Cotton Valley Completion Expected in Sixty Days

Completion of the recycling plant at Cotton Valley, Louisiana, is contemplated within 60 days. The plant, which will process 150,000,000 feet of gas daily, will have output of around 10,000 barrels of distillate and finished materials. It is the first instance of unitization of a whole structure for condensate recovery. The project is under management of the Cotton Valley Operators' Committee.

Ohio Standard Adding Alkylation at Cleveland

Standard Oil Company of Ohio is building an alkylation unit at its Cleveland, Ohio, refining plant. It will use the sulphuric acid catalytic process. Daily output of 3000 barrels is the estimated capacity.

Humble Proposes Cycling Plant for Katy Field

Largest cycling plant for the industry is that projected by Humble Oil & Refining Company and other owners of acreage in the Katy field near Houston. While the project has been under consideration for more than a year, first official confirmation of building came last month from H. C. Weiss, president, in his report to stockholders. Capacity of 200,000,000 feet of gas is anticipated.

California Standard to Build Cracking Unit

Standard Oil Company of California has completed plans for construction of a Houdry catalytic cracking and reforming plant at its El Segundo refinery in Southern California. Equipment for the installation, which will contribute to national defense through providing a greater volume of high-

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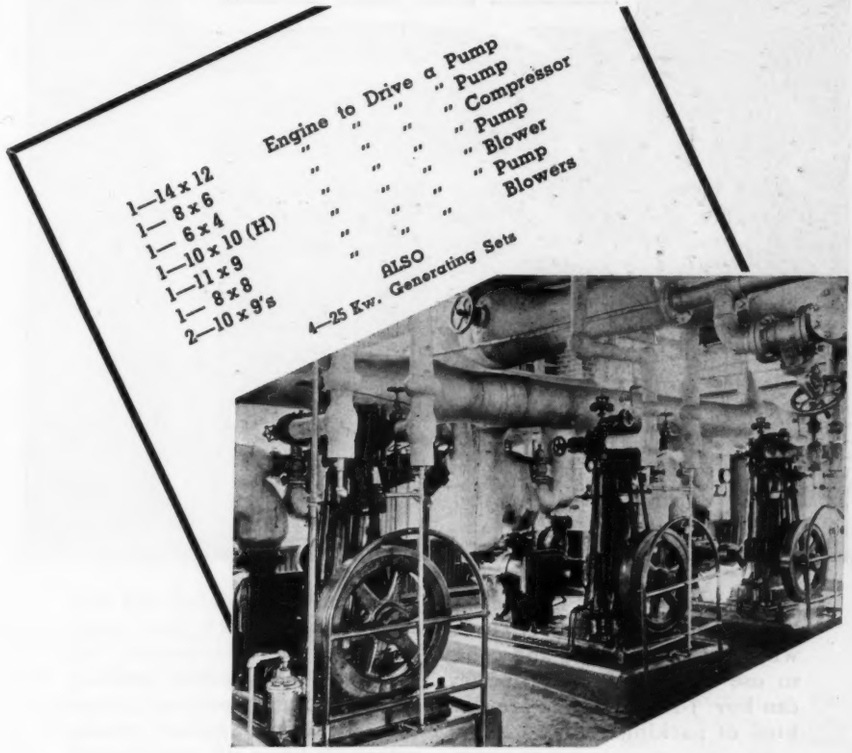

Above is a list of recent sales to oil refineries, indicating a continuing preference for the modern steam engine as the drive for important processing equipment.

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octane aviation gasoline, is now being ordered. It is anticipated that the plant will be in operation early next year. The cost will be in excess of $4,500,000.

The installation will be the only Houdry catalytic cracking and reforming plant on the Pacific Coast, and its construction is being undertaken after nearly two years of laboratory and semi-commercial scale operations have been under way by the company.

With completion of the installation, a new high-octane catalytic motor gasoline, different from any fuel now produced on the coast, will be made from California crude oil. The plant will also increase the company's production of high-octane aviation gasoline to an important extent.

Study Cycling Possibilities In California's Pomona Field

Operators in California's Pomona field have undertaken a unitization program looking toward a cycling project, which, if carried out, will be the first for the state. Tests are currently being made to obtain information from which it will be possible to determine practicality of a cycling program.

British American Building Lube Plant at Toronto

British American Oil Company will start construction immediately on a plant at Toronto to produce about 10,000,000 gallons of lubricating oils annually, with 20,000,000 barrels of gasoline as a by-product. Crude will be imported from the United States by tanker to Montreal, for trans-shipment in the company's tankers on the Great Lakes to the plant.

Recycling Output to Reach 50,000 Barrels

An estimate that output of cycling plants in Texas and Louisiana will reach 50,000 barrels daily by the end of 1941, and afterward hold to around that level, was given by Emby Kaye, vice president of Distillate Engineering Processes Company, Tulsa, before the monthly meeting of the Ark-La-Tex Division, Western Petroleum Refiners Association, at Kilgore, Texas, February 14. His subject was "Recycling and the Refiner."

Kaye expressed an opinion that output from distillate fields will never be as much as many fear because of economic considerations, which are given prior to plant building.

In regard to marketing output of these plants as motor fuel, he said he believed plant owners would find it preferable to sell output for pipe line delivery to refining plants, thus removing the product from direct competition with refinery motor fuel.

Natural Gasoline Output Up in 1940

Natural gasoline production in 1940 totaled 2,320,458,000 gallons, compared with 2,169,300,000 gallons in 1939, a daily average of 6,340,000 gallons against 5,943,000 gallons, it was reported last month by the United States Bureau of Mines.

December production, the bureau announced, totaled 207,900,000 gallons against 203,322,000 gallons in November, giving a daily average of 6,706,000 gallons against 6,777,000 gallons due to declines in the East Texas, Texas Gulf and Oklahoma City districts.

Stocks continued to decrease, those at refineries dropping from 126,798,000 to 119,238,000 gallons, and those at plants and terminals from 129,486,000 to 120,330,000 gallons during the month, it was stated. The total of 239,568,000 gallons at the close of the year, however, was materially in excess of the 185,682,000 gallons reported at the end of 1939.

Dinner in Honor Of John B. Terry

Honor guest for the annual dinner of Committee D-2 of the American Society for Testing Materials, Chicago June 23 to 27, will be John B. Terry, chief chemist of Standard Oil Company of California. The dinner will be part of the entertainment for the annual meeting of the society.

Terry has been a member of the committee for more than 20 years. T. H. Rogers, Standard Oil Company (Indiana), who was honor guest in 1940, is chairman of the committee.

Selection of the honor guest was unanimous at a recent committee meeting in Detroit, when T. A. Boyd, General Motors Corporation, Detroit, was re-elected chairman of Committee D-2. Dr. R. P. Anderson, secretary of the Division of Refining, American Petroleum Institute, New York, was re-elected secretary.

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The abstracts here presented are selected from the current literature of science and technology to afford reference to fundamental information not easily available to all readers. Abstracts of articles appearing in readily obtainable trade journals are not included.

Photostat copies of original articles will be supplied at cost by the Leslie Laboratories. Complete or limited bibliographies covering special topics by title, by abstracts, or in complete manuscript, will also be prepared and furnished at reasonable cost by the Laboratories.

Fundamental Physical and Chemical Data

Densities and Refractive Indices of Liquid Paraffin Hydrocarbons, M. L. HUGGINS, *Jour. Amer. Chem. Soc.* **63** (1941) pp. 116-20.

Although many studies have been made of the relationship between the structures of hydrocarbons and their densities and refractive indices, the publication of new data has made possible more exact study of the problem. Such a study is reported in the paper. The molal volumes of the normal paraffins are given quite accurately by an equation of the form $V_n = a + bn + (c/n)$. The molal volumes of several series of non-normal paraffins are given by relations of the form $V = V_n + d$. Molal refractions of paraffins in general are the sums of the characteristic bond refractions. The magnitude of a C-C or C-H bond refraction depends on the number of C and H atoms attached to each of the carbon atoms concerned. Simple equations for computing molal refractions and refractive indices of paraffins from their formulas have been deduced and tested.

Homologous Series of Alkanes, G. CALINGAERT, H. A. BEATTY, R. C. KUDER, AND G. W. THOMSON, *Ind. & Eng. Chem.* **33** (1941) pp. 103-6.

The subject of hydrocarbon densities and the change of density with temperature is briefly reviewed. Selected, smoothed values of the temperature coefficients of the density for the normal and branched-chain alkanes have been obtained through the collection, study and alignment of data from the literature. The molecular volumes in the liquid state at 20° C. of the normal alkanes from butane to eicosane are given by the simple equation $V = 30.392 + 16.375\ N + 74.44/N^2$ in which N is the number of carbon atoms. The molecular volumes in different homologous series of branched-chain alkanes, with the possible exception of the initial member of each series, differ from those of the corresponding normal isomers by a constant amount, characteristic of the series. The use of this alignment method to detect erroneous or suspicious density values in the literature is illustrated. Tabulation of densities and of the change of density with temperature are given for the alkanes from propane to eicosane, and for the branched-chain alkanes from methylpropane to 3-ethyloctadecane.

Some Physical Constants of Hydrocarbons and Their Structural Isomers, MIECZYSLAW-WOJCIECHOWSKI, *Proc. Amer. Acad. Arts Sci.* **73** (1940) pp. 361-9.

The boiling points and the changes of boiling point with pressure were determined for isomeric hexanes, heptanes, octanes, nonanes, and xylenes. The congealing points of some isomeric hexanes were determined. n-Hexane boils at 68.73$_3$° C. at 760 mm; 2-methylpentane boils at 60.26$_7$°; congeals at —153.7$_1$; 3-methylpentane boils at 63.26$_6$; 2, 2-dimethylbutane boils at 49.804, congeals at —102°; 2, 3-dimethylbutane boils at 58.02$_2$°, congeals at —132.7°; n-heptane boils at 98.41$_3$°, 2, 2-dimethylpentane boils at 79.21°; 2, 3-dimethylpentane, at 89.9°, 3-ethylpentane, at 93.3$_7$°, 3-methylhexane, at 91.8$_8$°, 2, 2, 3-trimethylbutane, at 80.9$_6$°, n-octane, at 125.65$_8$, 2, 2, 4-trimethylpentane, at 99.23$_4$°, n-nonane, at 150.8$_1$°, 2-methyloctane, at 143.2$_6$°, 3-methyloctane, at 144.1$_8$°, 4-methyloctane, at 142.4$_9$°, 2, 5-dimethylheptane, at 135.2$_1$°, 2, 6-dimethylheptane, the same.

Heats of Organic Reactions. X. Heats of Bromination of Cyclic Olefins, M. W. LISTER, *Jour. Amer. Chem. Soc.* **63** (1941) pp. 143-9.

A vacuum calorimeter for the study of reactions between volatile liquids is described. The vapor pressures of the olefins and of their dibromides were determined at several temperatures and from these data latent heats were calculated. The heats of bromination of several cyclic and acyclic olefins were measured in carbon tetrachloride solutions. Combination of these data led to calculation of the heats of bromination in the vapor phase. An analysis of these data suggests that a theory that assumes repulsive forces between non-bonded adjacent atoms is more consistent with experiments than a theory assuming attraction. However neither theory is capable, in a simple formulation, of accounting quantitatively for the observed changes in the heats of addition reactions.

Flame Temperature, B. LEWIS AND G. VON ELBE, *J. Applied Phys.* **11** (1940) pp. 698-706.

The measurement of flame temperature by line reversal, by wires, by thermocouples and by infrared radiation is discussed in a critical manner. In some cases the flame temperature may be higher than the theoretical, because of excitation lag in the vibrational degrees of freedom. The difference in temperature between soot particles and surrounding gas in luminous flames can be regarded as negligible. Methods of determining the temperature and the emissivity of such flames are described.

Chemical Compositions and Reactions

Configurations of the 2-Butenes, M. H. THOMAS AND F. E. W. WETMORE, *Jour. Amer. Chem. Soc.* **63** (1941) pp. 136-7.

For certain geoisomeric olefins it has been shown that the rate of mercuration of the trans isomer is less than that of the corresponding cis isomer. The authors have used this method to confirm the structures of olefins established by previous investigations. The metoxy- and hydroxy-mercurials of cis- and trans-2-butene were prepared. The rates of mercuration indicate that the low-boiling 2-butene has the trans configuration. Errors in methoxyl determinations have been shown and corrected.

Derivatives of Allylic Chlorides, M. TAMELE, C. J. OTT, K. E. MARPLE, AND G. HEARNE, *Ind. & Eng. Chem.* **33** (1941) pp. 115-20.

This paper, from the laboratories of the Shell Development Company, deals with the reaction of the allylic chlorides. These chlorides possess a reactive chlorine atom and an olefin linkage, and can be employed in a large number of syntheses, many of which have been tried for the first time in the Shell Laboratories. The present paper concerns itself with derivatives that can be made by reacting the chlorine atom in methallyl chloride. This substance is extremely reactive and can be employed in a large number of syntheses. Methallyl alcohol is produced on a semi-commercial scale in good yield by hydrolysis under pressure. A number of methallyl ethers have been obtained by reaction with alcohols and a variety of methallyl-substituted amines by ammonolysis. The chloride has also been reacted with metals and metal salts to from characteristic derivatives. Methallyl chloride has been available commercially for only a short time, and its uses can be expected to increase greatly.

The Common Basis of Intramolecular Rearrangements. VII. Inapplicability of a Free Radical Mechanism. Formation of 1, 1-Dimethylcyclopropane and Neopentane by the Action of Sodium on Neopentyl Chloride. Relation to the Mechanism of the Wurtz Reaction, F. C. WHITMORE, A. H. POPKIN, H. I. BERNSTEIN, AND J. P. WILKINS, *Jour. Amer. Chem. Soc.* **63** (1941) pp. 124-7.

The products of the reaction of one mole of neopentyl chloride and one mole of sodium were 13% 2, 2, 5, 5-tetramethylhexane, 36% neopentane, 25% 1, 1-dimethylcyclopropane, and a trace of isobutylene. The products of the reaction of 5 moles of neopentyl chloride and one mole of sodium were a trace of 2, 2, 5, 5-tetramethylhexane, 41% neopentane, 51% 1, 1-dimethylcyclopropane, and no isobutylene. The bearing of these results on the mechanism of molecular rearrangements and of the Wurtz reaction are discussed.

Manufacture: Processes and Plant

Mass Transfer and Friction in Turbulent Flow, T. K. SHERWOOD, *Trans. Amer. Inst. of Chem. Engrs.* **36** (1940) pp. 817-40.

The concepts of molecular and eddy diffusion are briefly discussed, and the importance of both is emphasized for the process of mass transfer between phases, as in engineering operations of drying, humidification, and gas absorption. It is shown how the various analogies between heat transfer and friction may be adapted to obtain analogies between mass transfer and friction. The resulting equations are given, based on the Reynolds analogy, the Prandtl-Taylor analogy, the Chilton-Colburn modification, the Murphree analogy, and the recent Karman analogy. They are compared with the experimental data of Gilliland on vaporization of of several liquids into a turbulent stream of air in a wetted-wall column. Excellent agreement was found in the case of the adaptation of the Karman theory. Many of the assumptions used by Karman are avoided in the derivation of an equation for steady-state transfer across a turbulent stream flowing between parallel plates, and the result is com-

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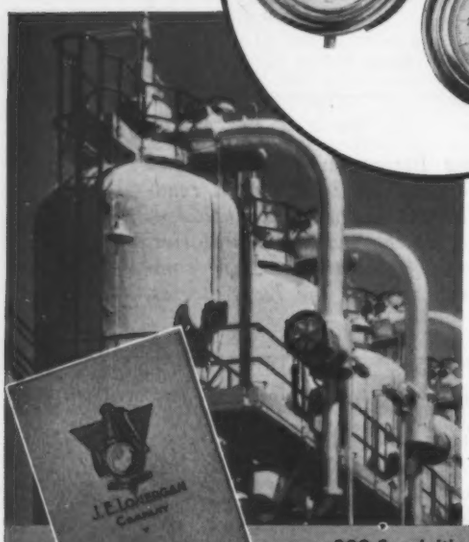

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pared with Woertz's data for this case. The agreement is less satisfactory than for vaporization from the inner walls of a round pipe.

Thermal Insulation for Industry, S. V. SAGINOR, *Chem. & Met. Engr.* **48** (1941) pp. 82-6.

The history of insulating materials is briefly reviewed, starting with the plastic cements developed in the 70's. The rock wools were developed about 1905, the diatomaceous silica materials about 1925, and, very recently exfoliated mica or vermiculite, as well as aluminum foil or other highly polished metals. Low temperature insulating materials are considered. The requirements of insulation for a wide variety of conditions are briefly reviewed. The data that are necessary to make an analysis of the proper type and thickness of insulation for industrial use are given. These include 12 questions, several of which have many sub-heads. A second list of 27 points that should be taken into consideration is given. A tabulation is included that gives the physical and thermal characteristics of the various types of commercial insulating material. Questions of structural strength and of service conditions under which insulating materials must be permanent are considered.

Liquefying Natural Gas for Peak Load Supply, R. W. MILLER AND J. A. CLARK, *Chem. & Met. Engr.* **48** (1941) pp. 74-6.

A novel chemical engineering method for storing of large quantities of gas in liquefied form to meet public utility peak loads in Cleveland is described. Plans have been made for the extension of a 12-inch high pressure line to the city limits at a cost of approximately $2,500,000. After reviewing work done with a pilot plant it was found that the same results could be had by building a liquid gas storage plant at a cost of approximately $750,000. The gas is compressed to 600 pounds, carbon dioxide and water are removed, the compressed gas is cooled by indirect contact with evaporating ethylene, the pressure is then reduced and part of the gas flashed, with the result that the remaining liquid is cooled to —218° F. This liquid is in turn partially flashed at a lower pressure and by this procedure cooled to —258° F. The liquid at this temperature is stored, and is pumped from storage to a steam heated evaporator to regenerate gas for city use. The storage tanks are spheres made of a special steel containing 0.09% carbon and 3½% nickel. They are of all-welded construction. The liquid gas-containing sphere is inside and concentric with an outer sphere, the 3-foot space between the 2 spheres is insulated with cork, the piping is made of copper with Van Stone joints, and bronze flanges and bolts. As far as possible automatic controls are used throughout the plant.

The Transference of Chemical Processes from Small to Large-Scale Operations, R. EDGEWORTH-JOHNSTONE, *Trans. Inst. of Chem. Engrs.* **17** (1939) pp. 129-36.

The author calls attention to the element of uncertainty in the prediction of full-scale operating results from pilot-plant experiments. The translation from pilot-plant to full scale operation is the most precarious in the entire program of developing a new process. The greatest risk falls just where the largest outlay is involved, reversing the principle that risk should decrease as capital invested increases. An application of the principle of similarity to chemical processes has yielded certain conclusions regarding the conditions under which results from a pilot plant may be reproduced on a large scale. Processes in which the reaction resistance is predominantly or entirely dynamical should be compared under conditions of dynamical similarity. Processes in which the reaction resistance is predominantly or entirely chemical should be compared under conditions of chemical similarity. Where both dynamical and chemical resistances enter to a substantial extent there is at present no sure method of predicting the effect of a change of scale. Chemical similarity can be established when certain dimensionless groups are equal. These groups are stated for homogeneous and for heterogeneous reactions. The matter of volume and of surface volume ratios in large and small plants are considered.

Recent Advancements and Applications of the Thermofor Kiln in the Petroleum Industry, T. P. SIMPSON, E. S. NICHOLLS AND J. W. PAYNE, *Trans. Amer. Inst. of Chem. Engrs.* **36** (1940) pp. 841-55.

Somewhat over a year ago the so-called Thermofor kiln was introduced to the petroleum industry as a clay burning unit for regenerating percolation clays. Since that time some improvements have been made in the design of the kiln, notably the adoption of a spirally-finned tube in place of tubes and loose angle pieces. In the Thermofor kiln the temperature of the clay or other solid, burned or heat treated, is positively controlled by

providing adequate heat transfer surface to absorb the heat of combustion. The distribution of air through the material being burned is uniform. The air flows counter-currently to the material burned. In normal operations no outside fuel is required, the necessary heat being supplied by combustion of the carbon deposits associated with the spent clay. Maintenance cost is low. Oxidation resistant alloy steels are used in constructing the heat transfer elements. Data are included in the article showing typical costs of earth recovery operations. The general layout of a Thermofor kiln, including the kiln salt tank and salt heater and cooler is given. Typical operating conditions are shown in a table. Four Thermofor kilns are now in operation, and others are under construction. The kiln can be built in large or small sizes. Two 10-ton units are now in service, as well as other units burning 45 tons and 120 tons per day. Other possible uses of the Thermofor kiln are suggested.

Economic Aspects of Synthetic Glycerine Production, E. C. WILLIAMS AND ASSOCIATES, *Chem. & Met. Engr.* **48** (1941) pp. 87-9.

In a previous article the author described the development of the production of synthetic glycerine from petroleum hydrocarbons in a pilot plant at Emeryville, California. In the present article the economics of glycerine is considered. The price has varied from 10c to 32c a pound in the last 20 years. Production has increased from 62 million to 184 million pounds. The sources of supply and the uses of glycerine are reviewed. The conclusion is reached that there is an opportunity for the synthetic process to stabilize price and also to guarantee a virtually inexhaustible supply of high grade glycerine at a reasonable price. Under these conditions it is probable that new uses for glycerine will be developed.

Petroleum Statistics, 1935-38, G. R. HOPKINS, *U. S. Bur. of Mines,* Economic Paper 20.

The author provides a useful history of petroleum statistics of the United States. Prior to 1925 statistics were collected by the Geological Survey. On July 1, 1925, the work was transferred to the Bureau of Mines. The historical development can be summarized as follows:

1882—Annual figures of crude-oil production by states and fields published by Geological Survey. Subsequently fewer and fewer figures by fields became available, owing to difficulties of obtaining details of pipe-line runs; data are now limited to a few of principal fields.

1883—Pipe-line stocks, back to 1871, first published.

1917—Bureau of Mines commenced statistics of refined products (production and stocks). This was primarily a military measure.

1921—Data on producing wells published by Geological Survey. Subsequent information is obtained from Oil and Gas Journal, Standard Oil Bulletin and American Petroleum Institute.

1925—Bureau of Mines took over Geological Survey statistical work. Tables of supply and demand for all oils first published. Statistics of imports and exports obtained from Bureau of Foreign and Domestic Commerce.

1926—Annual figures of fuel-oil distribution started.

1927—Figures first published of production of gasoline by cracking.

1933—First issue of Minerals Yearbook, in which all petroleum statistics were assembled.

1934—First figures obtained of crude-oil stocks by states of location, subsequently incorporated in weekly figures.

1939—Bureau of Foreign and Domestic Commerce established new classifications for import and export data, which agree more closely than previously with Bureau of Mines classification.

Each of the series of statistics referred to above is illustrated in the paper by monthly and annual figures relating to the years 1935-1938.

Products: Properties and Utilization

Annealing Atmospheres from the Combustion Products of Gaseous Fuels, A. G. HOTCHKISS, *Ind. & Eng. Chem.* 33 (1941) pp. 32-8.

The production of annealing atmospheres from the combustion products of gaseous fuels such as natural gas, producer gas, propane, and butane, is discussed. The history of the production of annealing furnace atmospheres is briefly given. The development and design of equipment for producing the atmospheres is considered. The behavior of various fuels in such equipment and the cost of controlled atmosphere gas from the several fuels is given. Purity requirements of atmospheres

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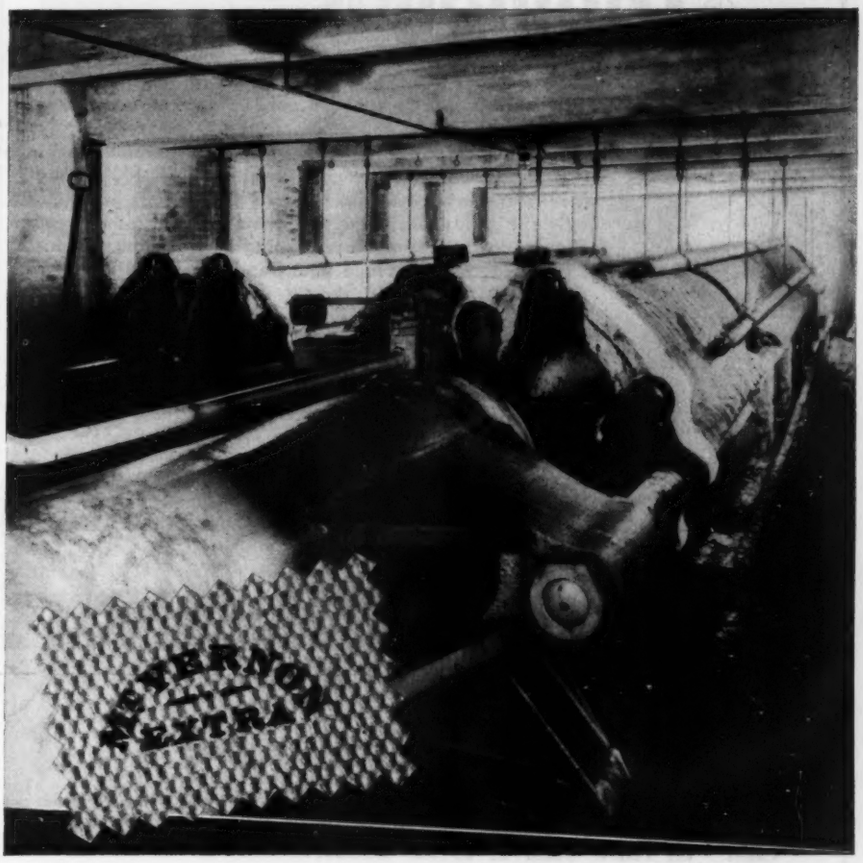

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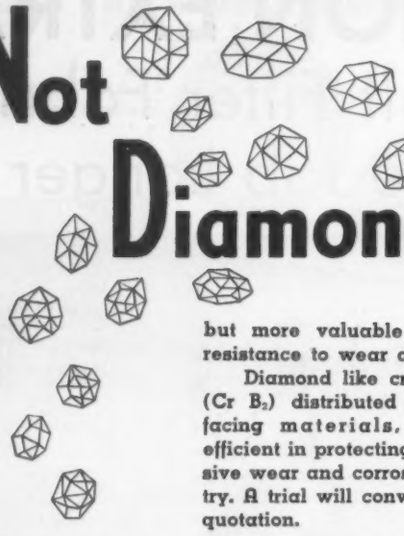

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for various uses are stated, and methods and equipment for removing such impurities as water, sulfur dioxide, nitric oxide, and carbon dioxide are described. The applications of atmospheres of various compositions to the treatment of specific metals are discussed.

Fuels for Diesel Engines in Marine Transportation, W. F. JOACHIM AND H. V. NUTT, *Trans. Am. Soc. Mech. Engrs.* **62** (1940) pp. 595-604.

The requirements of Diesel fuels and the manner in which these fuels have been developed are considered in some detail, with special attention to fuels for marine Diesel engines. The properties of Diesel fuels that affect engine performance are: ignition quality, viscosity, volatility and distillation range, carbon residue and impurities. Ignition quality is determined by such characteristics as structure, size and oxidation stability. Physical chemical indexes for ignition quality are unreliable in predicting the performance of doped fuels. The only reliable ignition quality determinations are those made by use of a running Diesel engine. Values are preferably expressed as the percentage of cetane in a blend of cetane and α-methyl-naphthalene that performs similarly to the fuel under test conditions. Maximum cylinder pressures and combustion shocks decrease with an increase in fuel ignition quality. For cold starting a minimum cetane number is required. Starting was found to be much easier as ignition quality increased from 20 to 50 cetane number. No definite conclusions can be drawn as to the effects of sulfur, water, corrosive impurities, ash, incomplete combustion, gum- and lacquer-forming components and cracked products on engine wear. However, it appears that sulfur above 0.7% causes a greatly increased rate of wear.

Rating of Diesel Fuels, P. H. SCHWEITZER AND J. S. CHANDLER, *Aut. Eng.* **30** (1940) pp. 135-41.

Tests were made on a range of fuels in the C. F. R. laboratory C. I. engine and in several high- and low-speed engines for the purpose of determining whether the laboratory ignition-quality rating is a true index of the performance of the fuel in commercial engines. Three test methods were used, namely, the R. C. R. method, in which the compression ratio is adjusted until the ignition lag becomes 15°; the air-throttling method, in which the air intake is throttled until a predetermined lag is obtained; and the variable-lag method, in which the engine is operated under normal conditions and blends of reference fuel are determined that give the same lag as the fuel under test. Details of an improved apparatus for measuring ignition lag are given. The conclusion was reached that the C. F. R. laboratory method underrates fuels by an average of 3 cetane numbers in comparison with the commercial engines. The average deviation between commercial engines is about 2 cetane numbers. The accuracy of the variable-lag method is inferior to the R. C. R. and air-throttling methods. The type of engine has more effect on ratings than the method used to rate fuels. Commercial engines can be compared by observing the slope of the ignition-lag vs. ignition-quality curves; the flatter the curve the less sensitive the engine to ignition quality; a flat curve is an advantage in service engines.

A Program for Industrial Lubrication. Current Practices and Problems, V. M. PALMER AND C. L. POPE, *Mech. Engr.* **62** (1940) p. 891.

About 5 years ago the Eastman Kodak Company formulated a plan for the standardization of lubricants, developed specifications, and distributed these to plant personnel and to companies selling lubricating oils. The number of lubricants used was reduced, standard tests were established, and better results achieved. The present paper reports on the progress of this program for the last several years. Lubricating devices have been standardized. The use of glass in these is excluded. They must be all metal or metal and transparent plastics. The overloading of bearings has been found to cause excessive leakage and contamination of products. A good rule is to fill the bearing one-third full of grease. Ball bearings 2 inches in diameter, turning 200 r.p.m. and operating at 140° F. have been properly lubricated with 1½ cc. of grease per bearing, applied at three-year intervals. The bearings are cleaned and then lubricated with a hypodermic needle in an air-conditioned room. The effect of temperature on lubricants is that the oxidation rate is estimated to increase in such a manner that the life of the lubricant is cut in half with each rise of 15° F. in temperature. If the oil temperature is below 140° F, there are many lubricants from which long service can be expected. The properties of the lubricant with respect to corrosion are more important than its viscosity and flash and fire points. A sodium soap grease emulsifies with water and so protects the bearing. In a corrosion test using ball bearings and comparing an inhibited sol-

vent-refined turbine oil with a similar oil not solvent-refined, it was found that the breakdown of the two oils was substantially the same, but the corrosion was much less when the non-solvent-refined oil was used.

Superheated Steam Cylinder Lubrication, C. H. S. TUPHOLME, *Eng. & Boiler House Rev.* **54** (1940) p. 132.

An oil suitable for lubrication in the presence of superheated steam should have a Saybolt viscosity of 165-195 sec. at 210° F., and should contain a small amount of animal fat. Many engineers have considered excessive oil feed necessary for the lubrication of steam cylinders in which superheated steam is used. This, however, is occasioned by the use of a straight mineral cylinder oil and to a misunderstanding of the values of high viscosity and high flash and fire points. If oil accumulates in the cylinder it may result in carbonaceous deposits.

Oxidation of Lubricating Oils, M. R. FENSKE, C. E. STEVENSON, R. A. RUSK, N. D. LAWSON, M. R. CANNON, AND E. F. KOCH, *Ind. & Eng. Chem., Anal. Ed.* **13** (1941) pp. 51-60.

The results reported are those of an investigation made to obtain an understanding of the mechanism of lubricating oil failures, and to determine the extent and kinetics of the oxidation reaction, and, so far as possible, the amount and nature of the products formed. An apparatus and procedure are described that permit determination of the rate of lubricating oil oxidation. Studies were made over the range of temperature of 130° to 180° C. using oxygen in a circulatory system. Methods were developed for the determination of substantially all the volatile and nonvolatile end products of the reaction. Ninety to 100 per cent of the oxygen absorbed by various oils was accounted for in the products determined. The principal product was water, which accounts for 40 to 60 percent of the reacting oxygen. Soluble saponifiable materials represent another considerable portion, while carbon dioxide, carbon monoxide, volatile acids, fixed acids, and precipitable products account for the remainder. The analysis of insoluble substances produced in laboratory and engine oxidation indicates that these are relatively highly oxygenated materials containing 14 to 24 percent of oxygen, and produced by polymerization or condensation of the oxidized oil. Molecular weight data and elementary analyses suggest empirical formulas for the insoluble substances. Through study of the oxidation of several commercial light oils it was found that the rates of oxidation vary widely, and that induction-type oxidation curves are common. In general, the results show the widely different oxidation characteristics of oils, and that much remains to be understood regarding the mechanism of oxidation before corrective measures can be established and applied.

Bituminous Paints, TH. TEMME, *Bitumen* **10** (1940) pp. 57-60.

The composition, properties, method of preparation and the principal uses of asphaltic paints, lacquers and emulsions are considered. It is stated that solutions of asphalt in tar oil or solvent naphtha cannot be brushed as well as solutions of tetralin or decalin. The latter solutions show fewer brush marks and irregularities in the film. The brushing properties of solutions of asphalt in toluene or solvent naphtha are considerably improved by the addition of about 20% tetralin.

Physical and Chemical Properties of Petroleum Asphalts of 50/60 and 85/100 Penetration, R. H. LEWIS AND J. J. WELBORN, *Proc. Assoc. Asph. Paving Tech.* **2** (1940) pp. 86-157.

Standard specifications that were considered to control the quality of asphaltic bitumen have been questioned since the introduction of bitumens from new crude sources and new refining processes. In order to determine how present bitumens conform to specifications, the Public Roads Administration requested producers to submit samples to the Federal specifications. These were examined according to Federal, A.S.T.M., Association of American State Highway Off. specifications and by other methods used for the control of quality. The investigation was confined to asphalt cements of 50/60 and 85/100 penetration. Forty samples of each grade were examined. The results were tabulated and crude source and method of refining indicated. The article describes the results of the test in great detail, and concludes that failure to pass many of the special requirements of bitumens from sources considered satisfactory justifies the discouragement of the use of discriminatory tests that do not measure quality. No definite correlation between test data and performance of the bitumens in service was found to indicate that any of the tests are true measures of quality or of durability.

YES NEW APPLICATIONS FOR NEW REFINING PROCESSES

Special drum type filters

Above: 25' Diameter "Singledisc"— one homogeneous fabric

Below: Reactor Screens

Right: Spider Covers

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. . . And so is our plant in which we make the answers to many a filtering and screening problem. Then, too, our men are up-to-date in the skill with which they fabricate wire and screen assemblies. This exceptional coordination of right design, proper plant facilities, trained specialists, has enabled us for 30 years to maintain a reputation among refiners for solving the seemingly unsolvable filtering and screening problem. Today, it keeps us alert to changing conditions and enables us to give you new applications right in step with your new refining processes. In stock we carry a larger selection of weaves, metals, alloys, than you will find anywhere else. And, if yours is a special problem you can depend on us for quick and intelligent response to your particular needs. The hundreds of case histories in our "Book of Experience" prove that Multi-Metal means better results at less cost.

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ALL MESHES
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New Equipment for the Modern Plant

Insulation

A. P. GREEN FIRE BRICK COMPANY

Three industrial insulations and an insulating cement, packed dry in 50-pound bags, have been announced by A. P. Green Fire Brick Company, Mexico, Missouri.

Sair-Seal is a plastic insulation for use in continuous operation to 1600° F. It is reclaimable up to 1200° F. It weighs 18 pounds per cubic foot, permitting one square foot to be covered 1-inch thick with 1½ pounds of material.

Sair-Kast 16 and Sair-Kast 20 are castable insulations for use in continuous operation in 1600° and 2000° F., respectively. Sair-Kast 16 has a cold crushing strength of 62 pounds, and has a rated conductivity of 10 percent that of fireclay brick. Sair-Kast 20 has a cold crushing strength of 171 pounds, and has a rated conductivity of 20 percent that of fireclay brick. Sair-Kast 20 has a cold crushing strength of 171 pounds, and has a rated conductivity of 20 percent that of fireclay brick.

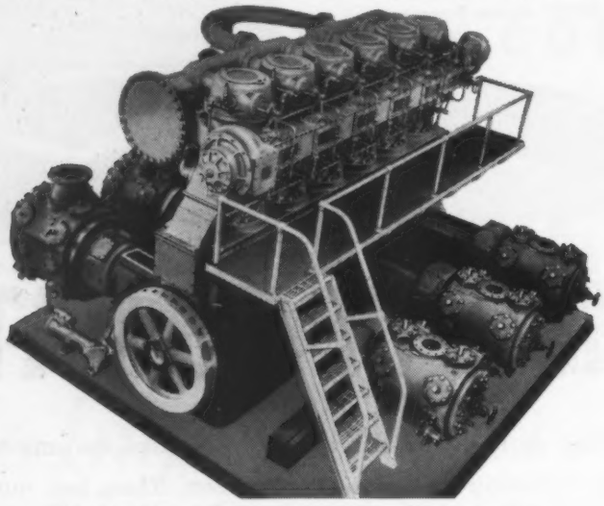
Sair-Cote is an insulating, coating and finishing cement designed to provide a hard, wearable insulating surface when applied over plastic or block insulation. It can be used at temperatures up to 1600° F., and dries to a surface that will take and hold a coating of industrial paint.

Compressor

CLARK BROTHERS COMPANY

A line of steam engine-driven angle compressors, available in sizes from 600- to 4000-horsepower, has been announced by Clark Brothers Company, Olean, New York.

The compressors have three to six power cylinders and a corresponding number of compressor cylinders in practically any arrangement desired. Power ends of the units are equipped with Unaflow steam cylinders.



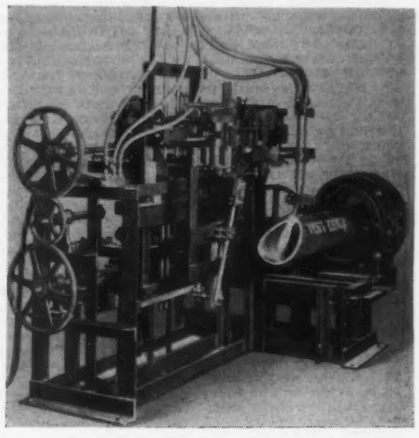
Clark's Steam Engine Driven Angle Compressor

Pipe Cutter

SPENCE ENGINEERING COMPANY

A machine designed to cut any size pipe to fit any pipe of the same size, or larger, at any angle or any offset, has been announced by Spence Engineering Company, Walden, New York.

Adjustments are made by four dials,



Spence Engineering's Pipe Cutter

and the cutting is accomplished by a standard cutting torch. The machine is hand operated, as the compound motion changes the cutting speed to an extent that the operator must gauge the speed to match the torch's ability to cut. The chuck has a set of adapters for each size of pipe.

An attachment is available to cut the corresponding holes in the other pipe.

Printer

CHARLES BRUNING COMPANY

A printer designed to operate with either cut sheets or roll stock and to print ink tracings at from 12 to 15 feet per minute, designated Model 55-BW, has been announced by Charles Bruning Company, 100 Reade Street, New York. The unit measures 32 inches wide, 62 inches long and 48 inches high.

The unit employs a speed indicator

Bruning's Model 55-BW Printer

A mighty fine mercury Recording Thermometer—built for long service and extreme accuracy by a firm who knows how to make good thermometers.

THE PALMER CO., MFGR.

Recording, Dial, Industrial and Laboratory Thermometers

2513 NORWOOD AVE., CINCINNATI NORWOOD, OHIO

Canadian Plant: **King & George Sts., Toronto**

Operating savings obtained from high steam temperatures and pressures would justify using expensive steels to avoid steam line trouble. Fortunately, an inexpensive Carbon-Molybdenum (0.50% Mo) steel does the job.

Its creep strength up to 1000° F, plus its easy weldability, make for light, leak-proof lines. The use of thinner sections sometimes reduces the already small cost differential over unalloyed steels.

Write for technical book, "Molybdenum in Steel".

CLIMAX FURNISHES AUTHORITATIVE ENGINEERING DATA ON MOLYBDENUM APPLICATIONS.
MOLYBDIC OXIDE—BRIQUETTED OR CANNED • FERROMOLYBDENUM • CALCIUM MOLYBDATE

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MOLY

at the center of the front, above the feed board, to make the speed of the machine visible to the operator at all times. The entire top of the machine serves as a return tray, with the return designed so the tracing enters the tray on the top of the print, the same way as it is inserted in the machine, and necessitating no reversing of the tracing when reinserting it into the machine.

Light source is a 55-watt mercury vapor quartz lamp, designed to furnish uniform exposure without flickering and to last 1000 hours. It is installed in a revolving 9-inch Pyrex contact cylinder.

The printer is equipped with a double centrifugal blower to reduce operating noise, and transmission and motor are resiliently mounted to reduce vibration. An automatic clutch, operating by a wide-range foot pedal, releases the feed roller so the tracing may be adjusted or removed when necessary.

A hinged section at each end of the printer allows access to all electrical controls and drive mechanism for cleaning and servicing. An automatic switch shuts off the light when the end housing of the tube and cylinder are removed. Ball bearings are employed and, except for electric motor bearings, are factory lubricated.

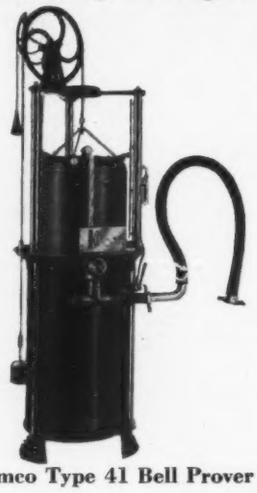
Meter Bell Prover

PITTSBURGH EQUITABLE METER COMPANY

A bell-type prover for meters used for measuring gas, designated Emco Type 41, has been announced by Pittsburgh Equitable Meter Company, 400 North Lexington Avenue, Pittsburgh.

In using the device, the bell is guided at both top and bottom by rollers, and a steel-cable-controlled counterbalance is used to reduce friction. Three-point adjustable bell suspension is designed to permit accurate bell alignment.

Three dial-type thermometers are provided to record temperature of the atmospheric air, temperature of the air in the bell, and temperature of the oil seal of the bell. Large airways and streamlined fittings are designed to provide high capacity with a minimum change in pressure. A straight scale with magnified scale at the main divisions has been provided to facilitate close reading.



Emco Type 41 Bell Prover

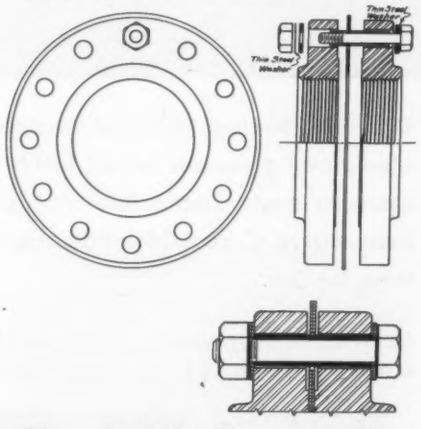
Insulating Flange

INDUSTRIAL ENGINEERING SERVICE

An insulating flange for pipe lines, designed to make unnecessary redrilling of the flanges before inserting the insulators, has been announced by Industrial Engineering Service, 310 Thompson Building, Tulsa.

The flanges, designated Wyaco, are made in sets for use on any fitting from 2- to 12-inch pipe size, and for use with flanges of series 200, 300, 400 and 600 pounds.

For new construction, the complete insulating flange joint, including steel flanges, can be furnished and correctly assembled before shipment. In other applications, SAE 4140 bolts of sufficient tensile strength are employed to compensate for the decreased diameter, enabling the insulator tubes to go through a standard flange hole, and the bolt, in turn, to go through the tube.



Wyaco Insulating Flange Assembly

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AIRETOOL ANNOUNCES

TUBE EXPANDERS

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TUBE CLEANERS
Sizes ½" I.D. to 20" I.D.
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FLYCUTTERS
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TUBE JIGS
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CALIPERS
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TUBE GAUGES
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POLISHING & BUFFING MOTORS
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PLUG SEAT PROTECTORS
•
TOOL TRUCKS

As oil refinery technology advances, the demand for higher temperatures and pressures makes it essential that all joints be properly rolled.

Airetool Tube Expanders are constructed in such a manner as to insure perfect joints between tubes and headers. Cage and mandrel stops on the tools are quickly and accurately set for proper rolling depths and flare.

In addition to controlled depths and flared surfaces the thrust is taken on ball bearings, permitting rotation without any additional forward movement of cages or mandrel. In arresting forward movement of the tool and revolving the cage and mandrel all ridges are ironed out, providing a smooth, polished, rolled surface, free from erosion points.

Write for complete information on all types Airetool Tube Expanders for all tube sizes.

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KELLOGG HAS THE SOLUTION TO MANY PROBLEMS FACED BY THE REFINER TODAY

Faced with today's conditions, refiners should recognize the fact that only an organization versed in all phases of refining technology and with a background of commercially successful installations covering a wide variety of processes can solve their problems. Many refiners have formed a habit of consulting The M. W. Kellogg Company as new problems arise. They have found this both satisfactory and profitable.

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LICENSING AND CONSTRUCTION AGENTS under United States and foreign patents for:
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Paint

THE B. F. GOODRICH COMPANY

A paint to protect metal surfaces against chemical reactions, designated Koroplate, has been announced by The B. F. Goodrich Company, Akron, Ohio. It is designed to resist all acids except concentrated formic and acetic, and not to be affected by brass-, chrome-, nickel-, cadmium-, zinc-, copper-, silver- or tin-plating solutions.

Base of the paint is Koroseal, a synthetic material created from polyvinyl chloride, derived from coke, limestone and salt. The paint is liquid at room temperatures, and requires no heating before application. At ordinary temperatures it may be either brushed or sprayed, and can be thinned with either brush or spray thinners when necessary. It is made only in semi-glossy black, and must be used in conjunction with a Koroseal primer with similar characteristics.

Pipe Cutter

THE RIDGE TOOL COMPANY

A 4-wheel pipe cutter, designed for work in close quarters and for increased cutting speed, has been announced by

Ridge Tool's Model 42 Pipe Cutter

The Ridge Tool Company, Elyria, Ohio.

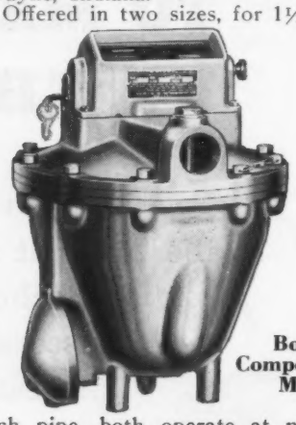
Designated Model 42, it has been built to cut iron, steel or brass pipe.

Meter

S. F. BOWSER & COMPANY

A meter that compensates measurements on a 60° F. basis, with adjusting scale covering API gravity from 6° to 90° and coefficient of expansion from 0.00035 to 0.0009, has been announced by S. F. Bowser & Company, Fort Wayne, Indiana.

Offered in two sizes, for 1½- and 2-



Bowser Compensating Meter

inch pipe, both operate at maximum pressures and temperatures of 50 pounds and 130°. The 1½-inch meter passes a maximum of 50 gallons per minute, the 2-inch meter passes 110 gallons. The small meter employs tapped female inlet connections, and the large meter is flanged.

Body of the meter, designated Model 764-AT, is cast iron, and pistons are of leather-sealed type. Compensation of measurement is accomplished by controlling the amount of liquid displaced, and there is no compensating of the recording mechanism.

Developing Machine

CHARLES BRUNING COMPANY

A developing machine, designated Model 159 Volumatic and designed for use with the company's Model 75 printer, has been announced by Charles Bruning Company, 100 Reade Street, New York. Using the combination, one

Bruning's Volumatic Developer

operator can perform the entire printing and developing process.

In operation of the developer, sensitized paper and tracings are fed into the machine at the front, where they are immediately exposed to the printer section. A vacuum separator roll at the discharge point of the printer separates

Success Story of LATTICE-BRAID Packing!
"On a centrifugal pump handling silicate of soda at 3000 F. Lattice-Braid has lasted four times as long as any other packing heretofore tried and is still giving 100% service."
"After three months service Lattice-Braid on a plunger type mine pump handling water containing excessive sediment is still performing perfectly."
"Lattice-Braid is the best packing we have ever seen for sand pump service."

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GARLOCK LATTICE-BRAID Packing is available in the following styles: GARLOCK 730 for centrifugal and rotary pumps handling hot or cold water, caustic solutions or weak acids. GARLOCK 731 for rods operating against steam, gas, acids, lye and caustic soda solutions. GARLOCK 732 for heavy duty service against high pressure steam or hot oil. GARLOCK 736 for centrifugal or rotary pumps handling acids or strong chemical solutions. GARLOCK 751 for centrifugal or rotary pumps handling cold oil or water.

MANY TYPES OF SERVICE. Since it was introduced several months ago the new Garlock LATTICE-BRAID Packing has proved itself by superior performance on many types of service.

LONGER LIFE. The unique structural design of LATTICE-BRAID holds strands together (even when the material is worn far beyond the serviceable limits of wear of ordinary braided packings), provides unusual flexibility and imparts semi-automatic pressure action. Write for illustrated folder!

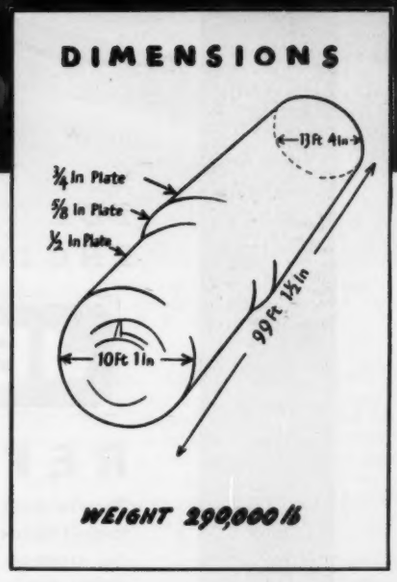
THE GARLOCK PACKING COMPANY

PALMYRA, NEW YORK

Tulsa, Okla. **Houston, Tex.** **Los Angeles, Calif.**

GARLOCK

TOWERS... and other refinery vessels built to your specifications by C-E



The same facilities, skill and personnel, which are used to build many of the world's largest high pressure, high capacity boilers are available to you for the fabrication of all types of pressure vessels required in the oil industry.

To the men in the C-E Shops where this work is produced, your specifications, however exacting, are certain to be thoroughly understood and faithfully executed for they have produced during the years a large quantity of all types of refinery pressure vessels.

The complete facilities which are utilized by C-E for the fabrication of quality pressure vessels include an unusual plate bending press, modern x-ray testing equipment, a large stress relieving furnace, chemical and physical laboratories in addition to necessary boiler, welding, pattern and machine shops.

Ask C-E to quote on your next pressure vessel requirements. A-577

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C-E pressure vessels are produced at the following plants:

HEDGES-WALSH-WEIDNER DIVISION
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C-E PRODUCTS INCLUDE ALL TYPES OF BOILERS, FURNACES, PULVERIZED FUEL SYSTEMS & STOKERS; ALSO SUPERHEATERS, ECONOMIZERS & AIR HEATERS

the tracings from the exposed prints, allowing the prints to pass automatically to the developing and drying sections. The tracing is returned to the operator, while the developed print is delivered flat and dry at the rear of the machine.

The developer consists of a separator roll, water roll, and a series of bands that carry the developed prints through the drying section. The developing section is driven by the printer, and is synchronized to operate at the same printing speeds with a range to 25 feet per minute.

Motor

CENTURY ELECTRIC COMPANY

A new line of totally enclosed fan-cooled motors, designed to provide protection where air is foggy with metal cutting solutions or where there are abnormal quantities of metallic, abrasive and other dusts in the atmosphere that would ordinarily injure or clog the windings of a general purpose open motor, has been announced by Century Electric Company, 1806 Pine Street, St. Louis, Missouri.

Century Electric's Fan-Cooled Motor

A non-sparking fan in provided to force cooling air through large passages, so designed that a 5/16-inch rod will not pass through them. The motors are finished in a smooth machine gray.

V-Belt

THE CINCINNATI RUBBER MANUFACTURING COMPANY

A multiple V-belt, employing a heavy elastic fabric envelop to take up the outside wear and to permit ready flexing and give gripping power, has been announced by The Cincinnati Rubber Manufacturing Company, Cincinnati, Ohio.

Load is carried by a section of high-tensile, low-stretch cords impregnated with liquid rubber and imbedded in a cushion of rubber to provide lengthwise flexibility and easy flexing around the pulleys.

Cincinnati Rubber's V-Belt

Uniform cross sections are designed to enable each belt to seat itself in the groove, and each belt is matched so that it will carry its equal share of the load. The belt is available in all sizes.

Test Rig

LINK-BELT COMPANY

A variable-speed test rig, combining a positive infinitely variable speed transmission and an adjustable mounting bracket on a welded steel base, and designed for testing generators, magnetos, governors, vibrators, pumps, springs, bearings and other specialized equipment, has been anonunced by Link-Belt Company, Philadelphia.

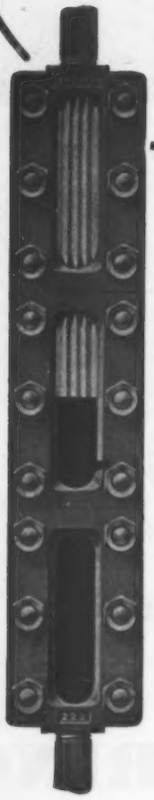
The rig is used to determine whether the equipment tested runs true, functions efficiently, carries the load properly, and for calibrating.

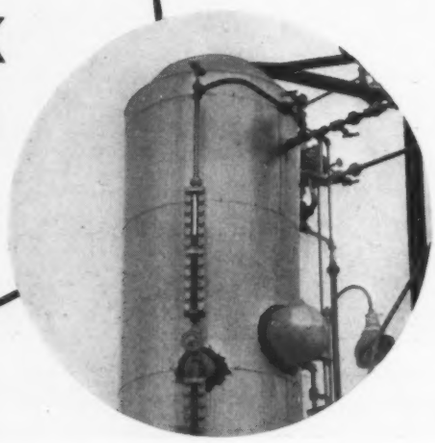
The mechanism to be tested is placed in position on a horizontally adjustable mounting bracket, moved up as required, and then connected to the variable-speed output shaft of the transmission. The bracket can be constructed to suit the design of the parts to be mounted and tested.

Variable Speed Test Rig

For Visibility's Sake make it

REFLEX GAGES





FOR THAT ADDED SAFETY FACTOR MAKE IT

JERGUSON

REFLEX GAGES

They're built to stand up under the high pressures and temperatures encountered in refinery operations. Study the cross-section and note the heavy bar steel U-bolt which reinforces the assembly. Metal parts are rugged, of special alloy steels, to take the brunt of the stresses. The glass is the best obtainable, selected for high temperature work and carefully tempered to withstand pressures.

The name JERGUSON has long been identified with the highest quality column gages. You can rely upon them.

JERGUSON GAGE & VALVE CO.

87 FELLSWAY SOMERVILLE, MASS.

Reducing Elbow

MIDWEST PIPING & SUPPLY COMPANY

A reducing butt-welding elbow, designed for use where it is necessary to change both direction and pipe size, has been announced by Midwest Piping & Supply Company, 1450 South Second Street, St. Louis.

The wrought steel of the elbow is worked in compression, rather than being extruded or stretched, and is stress relieved after forming, welding and compression-sizing operations. Ends are machine faced and beveled. The elbow is made in 33 regular sizes, ranging from 2 x 1 to 12 x 6 inches. It is made of other materials on special order.

Midwest's Reducing Elbow

Motor

U. S. ELECTRICAL MOTORS, INC.

A vertical explosion-proof motor designed for applications in Class I, Group D and in Class II, Group G locations, as defined by the National Board of Fire Underwriters, has been announced by U. S. Electrical Motors, Inc., Los Angeles.

The unit is fan-cooled, and features asbestos-protected windings. It is offered with a variety of mounting flanges, and regardless of the design of the machine, a mounting bracket is available to fit without additional adaptors or plates.

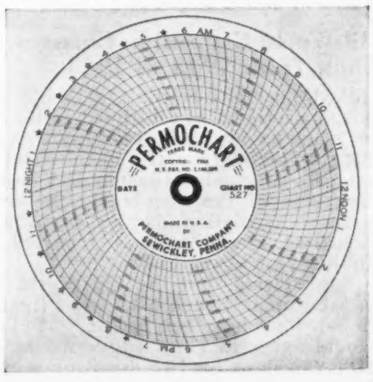
Instrument Chart

PERMOCHART COMPANY

A recording instrument charts for continuous reuse has been announced by Permochart Company, 517 Chestnut Road, Sewickley, Pennsylvania.

Made of Vinylite plastic, the charts can be constantly reused, as the previous day's ink record is removed from its surface with a damp cloth. The charts are designed not to curl, are non-flammable, and are oil-, gasoline- and grease-resistant. Centers are reinforced to prevent deterioration, even from holding devices using sharp projections. Printing and laminating have been improved so that the charts are clearer and cannot separate at the edges. Each chart is guaranteed for daily use over a period of two years under normal working conditions. They are made for all types of recording instruments which use circular charts, and special charts can be made upon request.

For applications where it is necessary to save chart records, the company has established a microfilm photographic system for recording and filing. The method is designed to reduce filing space by 98 percent of that normally used.



Transmission Belt

MANHEIM MANUFACTURING & BELTING COMPANY

A flat transmission belt, designated Octopus and designed to combine maximum pulley grip to end slippage and great resilience to stop stretch, has been announced by Manheim Manufacturing & Belting Company, Manheim, Pennsylvania.

Combining 35-ounce duck with a special impregnating material, the belt is described as requiring no belt dressing. It is not recommended for oily drives.

THIS GAS OIL CRACKING FURNACE *features Kellogg Supported Arches and Walls made of lightweight Armstrong's Insulating Fire Brick. These brick assure quicker heating—quicker cooling, an aid to maximum production. Furnace designed and built by the M. W. Kellogg Company.*

WEIGHT is a major factor to consider in building many heat processing units . . . especially in refineries located on sandy or marshy ground. That's one reason why *lightweight* Armstrong's Insulating Fire Brick are so often used in these installations.

The fact that Armstrong's Brick are unusually light in weight does not detract from their other physical characteristics. These brick constantly meet high standards for crushing strength, thermal conductivity, tensile strength, and spalling resistance. They give satisfactory performance in almost any type of furnace installation.

Big savings of time and money are possible when Armstrong's Insulating Fire Brick are on the job. For they have exceptionally low heat storage capacity which means they heat up quicker and cool off quicker. Furnaces can be entered and repaired sooner and, in some instances, are back into production within a few hours. Standard sizes of Armstrong's Brick can be readily cut and specially shaped right on the job, thus eliminating any need for large stocks of unusual sizes and shapes for repair purposes.

If you want to speed production, save fuel, and assure more accurate temperature control, it will pay you to find out about Armstrong's complete high temperature line now. Write today to Armstrong Cork Company, Building Materials Division, 1001 Concord Street, Lancaster, Pennsylvania.

Armstrong's

HIGH TEMPERATURE INSULATION

Color now aids the easy and accurate identification of the five types of Armstrong's Brick

BUSINESS NOTES

Steel Tube Institute Launches Research Program

The Seamless Steel Tube Institute, 3510 Gulf Building, Pittsburgh, has announced adoption of a program of market research and related activities, to be put into effect March 1 under the direction of W. A. Cather, now advertising manager of The Babcock & Wilcox Company, 85 Liberty Street, New York.

In his new position, Cather will operate out of the institute's office in Pittsburgh and the offices of the Michel-Cather organization at 2 Park Avenue, New York.

Manning, Maxwell & Moore Announce Plant Expansion

Manning, Maxwell & Moore, Inc., has announced an expansion program that includes addition of a sixth floor to its plant in Bridgeport, Connecticut, with leasing of an additional 50,000 square feet of space across the street.

The company's Hancock Valve Division, located at Boston, Massachusetts, has acquired an additional four-story factory building which will be devoted exclusively to manufacture of steel valves. Equipment is being added for the newly acquired space.

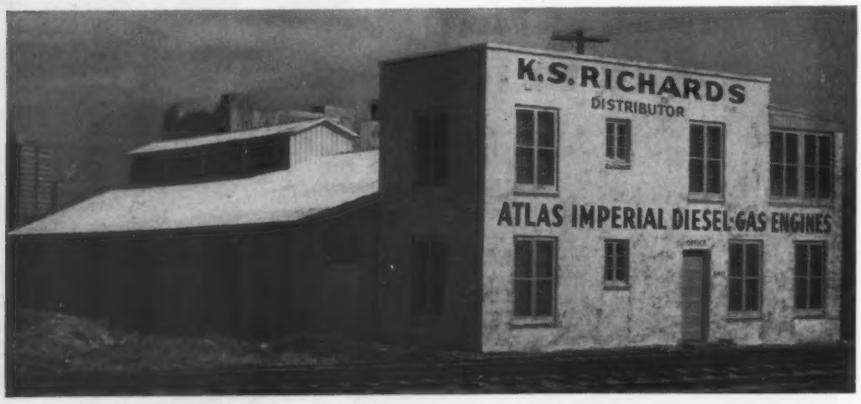
Sarco Changes Location of New York Headquarters

Sarco Company, effective March 1, changed the location of its head offices in New York from 183 Madison Avenue to 475 Fifth Avenue, where the company occupies the entire twenty-fourth floor.

Douglas-Guardian Corporation Holds Three-Day Convention

Representatives of Douglas-Guardian Warehouse Corporation from 15 branch offices held a three-day convention in Chicago last month.

Those taking part in the meeting included Jay Weil, president; E. A. Baker, vice president, and D. C. Dickinson, H. W. Pretzel, E. R. Kubecker, Boyd Dicus, O. B. Burdick, R. A. Barton, W. S. Thompson, A. J. Walker, S. D. Hart, Robert Ruffin, D. J. Hassel, D. B. MacDuff, Mrs. A. K. Laing, H. F. Scherer, T. E. Wheedleton, J. Leitch, Edwin Horvath, K. A. Campbell, J. K. Simpson, E. C. Yuille, F. J. Cartwright, Alan Valiant, E. C. Thomson, Edward Schneider, Miss H. Johns, G. R. Bodet, Mrs. V. W. Lowry, C. E. Gartman and Fred R. McClure.



K. S. Richards, distributor for Atlas Imperial diesel engines, has consolidated his office, shops and warehouse stocks at 840 West Vickery, Fort Worth.

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Glyco Products Company Moves to Larger Quarters

Glyco Products Company has moved its offices, plant and laboratories from 148 Lafayette Street, New York City, to larger quarters at 230 King Street, Brooklyn. The building, which was erected to their specifications, has improved shipping means, including railroad sidings and water freight facilities. New and modern equipment has been installed to increase and improve production facilities.

Allegheny Ludlum Increases Special Steels Capacity

Allegheny Ludlum Steel Corporation is increasing its capacity for melting special steels by approximately 4000 tons per month. The increased capacity is being made possible by contracts just placed for installation of two additional electric melting furnaces at the plant at Brackenridge, Pennsylvania.

The company also has awarded contracts for additional rolling mill equipment to handle the enlarged tonnage production.

Allegheny Ludlum Steel Opens New Coast Office

W. F. Detwiler, board chairman of Allegheny Ludlum Steel Corporation, has announced completion and opening of the company's new warehouse and offices at 4915 Pacific Boulevard, Los Angeles.

Vinson Supply Company Moves Dallas Office

Vinson Supply Company, Tulsa, has announced movement of its Dallas offices from the Tower Petroleum Building to 1302 Gulf States Building. Granville B. Lane is supervisor of the offices.

Ethyl Gasoline Corporation Changes Tulsa Location

The Tulsa office of the Ethyl Gasoline Corporation has been moved to 525 National Bank of Tulsa building.

Oil-World Exposition Changes Show from 1942 to 1943

Postponement of the Oil-World Exposition, originally scheduled to be held in Houston in April, 1942, until April, 1943, was voted by the membership at a meeting held in Houston last month. The vote of the membership followed a recommendation of the exposition's executive committee, as reported by John R. Suman, president.

Suman said that the Oil-World Exposition had hoped that the International Petroleum Exposition at Tulsa would agree to plans suggested by the Houston show for two expositions every

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Universal Oil Products Company, Chicago,
A. C. S. Monograph No. 78

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VOLUMES II, III and IV will follow in short order.

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In the four volumes comprising this work, all the information available up to November, 1938, has been collected and evaluated.

Each volume will present the most reliable values obtained for the melting point, boiling point, specific gravity and index of refraction of the hydrocarbons.

The first volume deals with the paraffin, olefin, acetylene and other aliphatic groups, together with all the data from which the values given are derived. The work is restricted to these four constants chiefly because they are the ones most frequently employed in identifying hydrocarbons, and in industrial engineering. The basic idea underlying this four-volume compilation has been to contribute to our fundamental knowledge of hydrocarbons from the scientific as well as the pragmatic point of view. It will be of inestimable service to all organic chemists, and to many other workers in industries in which hydrocarbon chemistry plays an important part, such as the petroleum, natural and manufactured gas, coal and coke, rubber, plastics, pharmaceutical and dyestuff industries.

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WATSON-STILLMAN
Forged Steel Fittings

Southwest district sales representatives of Pittsburgh Equitable Meter Company and Merco Nordstrom Valve Company, Pittsburgh, held a sales meeting in Tulsa recently. Pictured attending the meeting are, left to right, in the front row: L. R. Van Arsdale; W. R. McLaughlin; F. A. Arnesen; A. E. Higgins, vice president in charge of sales; J. L. Cottrell; A. J. Kerr, district manager; A. D. MacLean, vice president and chief engineer; Roy R. Bush; O. W. Barnett, and Dean D. Collins. In the back row are, left to right: L. A. Babin, M. D. Gilbert, J. W. Northcutt, Herbert Parker, J. E. B. Lundy, Carl E. Baird, C. K. Madison, Glynn De Haas, F. N. Dillman and Tom Stacy.

four years, alternating between Houston and Tulsa, but that the International Petroleum Exposition would make no change from its announced plan of holding the International Petroleum Exposition on alternate years. Tulsa has an exposition scheduled for 1942, which would mean that if the Oil-World Exposition went ahead with its plans for a show in 1942, there would be two shows within a month of each other.

He also referred to the need for additional facilities for the Houston show, which had been promised by a previous city administration but plans for which could not be whipped into shape by 1942.

Dr. R. P. Anderson, secretary of the Refining Division, American Petroleum Institute, has been re-elected chairman of the American Standards Association's Standards Council. He has represented the Institute on the council since 1934 and previously has served one term as chairman.

Supply Personals

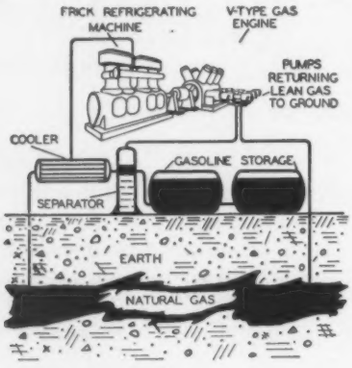
W. F. Williams has joined Manning, Maxwell & Moore, Inc., Bridgeport, Connecticut, and will work with accounts in the oil industry. He will make his headquarters in Chicago.

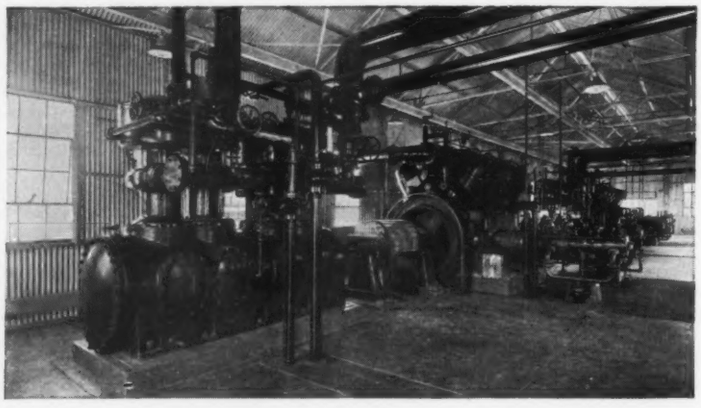
Addison C. Armstrong has joined Worthington Pump & Machinery Corporation as manager of the Ordnance division of its works at Holyoke, Massachusetts. He was formerly affiliated with Truscon Steel Company as a departmental manager and previous to that was associated with Bartlett-Hayward Company and Campbell Metal Window Corporation.

Harold C. Eddy has been named general manager of Petroleum Rectifying Company of California. A graduate of Colorado School of Mines, he has been with the company for 27 years. For the past several years he has been actively engaged in developing the company's electrical desalting process.

S. Merton McMahon has become associated with Pittsburgh Steel Company, as salesman for oil country tubular goods in Eastern states. He was several years associated with The National Supply Company in Ohio and Illinois, and later with Continental Supply Company in Texas. His headquarters will be in Pittsburgh.

W. H. Womack, who for 20 years has





Gasoline now made from natural gas with

Tide Water Associated-Seaboard Oil are doing it at the rate of 38,000 gallons a day in their new plant near Palestine, Texas, using the Vaughan recycling process shown in the sketch.

Two big Frick 4-cylinder compound compressors, of unique design, condense the high-octane gasoline by cooling 40 millions cubic feet of natural gas, daily, to temperatures near zero.

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For instance, in refineries where distances are great and the condensate cannot be returned to the boiler, you will find thousands of Sarco No. 87's—the liquid expansion steam trap which is not only nonfreezing but is in itself a fairly accurate temperature control. It is used to drain heating lines on the orifice lines to steam, gas and oil meters; and as an inexpensive form of temperature regulation for storage tanks, tank car heating coils, etc. Ask for Catalog No. 48.

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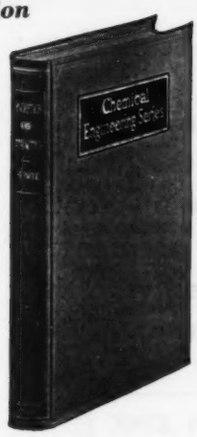

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Associate Professor of Chemical Engineering, Massachusetts Institute of Technology

278 pages — 91 illustrations — $3.50

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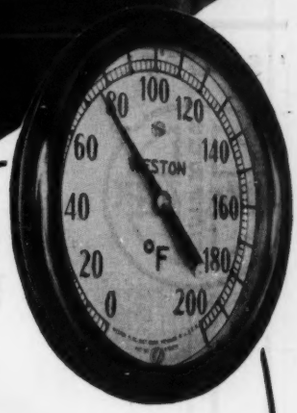

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been connected with the production and oil equipment sales departments of the J. B. Beaird Corporation, Shreveport, has been appointed a director of the National Rifle Association. As a marksman, Womack's honors have included presidency of the Louisiana State Rifle Association, Louisiana and Texas championships, and coach for the Dewar International Rifle Team at Camp Perry in 1940.

John T. Ryan, 57, president of Mine Safety Appliances Company, Pittsburgh, died February 20 in Miami, Florida. A native of Huntingdon County, Pennsylvania, he attended Juniata College and Pennsylvania State College, from which he graduated in 1908 with a B.S. degree in mining engineering. In 1934, he was given the degree of honorary engineer of mines by the same institution. After graduation he became affiliated with Rocky Ridge Coal Company, and later was superintendent and mining engineer for Langdon Coal Company, Huntingdon, Pennsylvania. From 1911 to 1914, he was in charge of mine rescue and safety, and the mine lamp testing division of the United States Bureau of Mines. In 1914, he and George H. Deike, Pittsburgh, founded Mine Safety Appliances Company.

L. L. Smith, assistant treasurer of The B. F. Goodrich Company, Akron, Ohio, has been named treasurer, taking over duties formerly held concurrently with those of vice president by George W. Vaught. A. A. Sprague, board chairman of Sprague-Warner Company, Chicago, was elected to the board.

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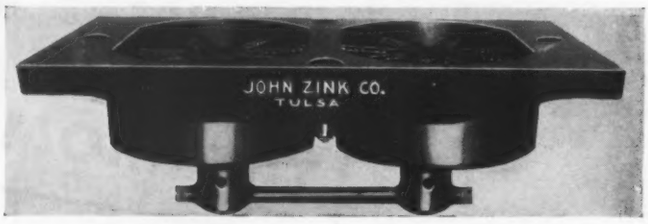

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342 Madison Ave.

William G. Theisinger, since 1935 welding and metallurgical engineer for Lukens Steel Company, Coatesville, Pennsylvania, has been appointed director of welding research for the company. Born in Carlisle, Pennsylvania, he attended public schools in Harrisburg, Pennsylvania, and joined Harrisburg Steel corporation. In 1925, he became associated with the New York Board of Transportation in development of welding inspection. In 1930, Theisinger entered Harvard University from which he graduated in 1934 with the degree of Bachelor of Science. During the summer of 1934, he served Western Pipe and Steel Company of California as consulting engineer on high-amperage automatic welding. In 1935, on completing post-graduate work at Harvard University, he received a doctor of science degree.

W. G. Theisinger

B. R. Schabarum has been named sales manager of the Texas division of The National Supply Company, with headquarters at Fort Worth. He has been with the company since June, 1926, when, following his graduation from the California Institute of Technology in mechanical engineering, he became a member of the company's engineering staff at Toledo. From 1926 to 1931, he engaged in laboratory research at Toledo and field investigation in the California, Mid - Continent and Gulf Coast areas. In 1931, he was assigned to the field engineering staff at Tulsa. In June, 1938, Schabarum was transferred to the field engineering staff of the Texas division at Ft. Worth, and the following year joined the company's sales staff in the Texas division. On June 1, 1939, he was appointed assistant sales manager of the division and continued in this capacity until his recent appointment as division sales manager.

B. R. Schabarum

G. A. Palmer, southwestern representative for the De La Vergne Engine Sales Division of Baldwin - Southwark Corporation, Philadelphia, with headquarters in Houston, died February 9. Palmer, who had been suffering from heart trouble for the past two or three years, had been located in Houston for 24 years as sales representative for De La Vergne engines. He had recently been given the added appointment as southwestern repres-

G. A. Palmer

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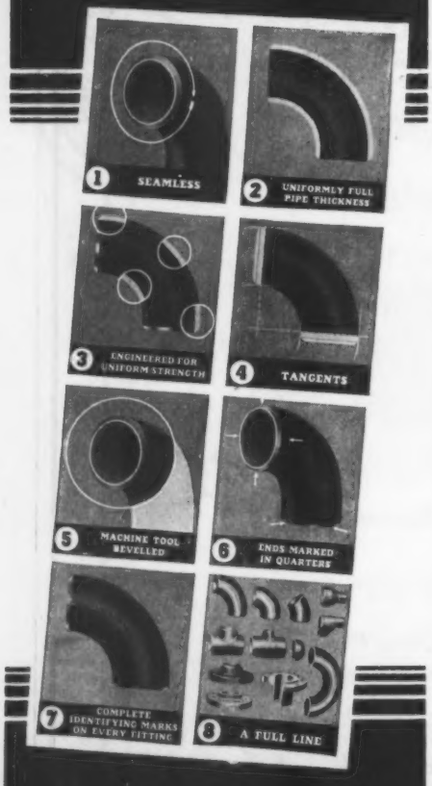
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sentative for The Midvale Company, Nicetown, Pennsylvania.

G. L. Irvine has been appointed manager of a new Apparatus Agency Sales Section of General Electric Company's Industrial Department.

C. E. Naylor, president of Maintenance Engineering Corporation, has been named chairman of the publicity committee of the Houston Chamber of Commerce.

J. S. Overstreet has been placed in charge of wire and cable sales for General Electric Company's Wire & Cable Division.

William W. Crawford, president of The Edward Valve & Manufacturing Company, East Chicago, Indiana, died in Miami Beach, Florida, February 19, 1941. He was born in Washington, Connecticut, in 1882, and attended Beloit and Oberlin colleges. He started his business career as newspaperman in El Paso, Texas, in 1905, joined the staff of the Chicago Record Herald in 1906, was appointed manager of the Chicago Automobile Club in 1907, entered traction business as secretary-treasurer of the Chicago City and Connecting Railways from 1910 to 1920, was secretary-treasurer and director of the Chicago Interurban Traction Company from 1912 to 1928, and receiver for the same organization 1922 to 1928. He was president of McClellan Refrigerating Company from 1921 to 1928, and president of The Edward Valve & Manufacturing Company since 1923.

L. C. Allenbrand has been named manager of the sales development division of Caterpillar Tractor Company, Peoria, Illinois, succeeding G. E. Spain, who has been advanced to general sales manager. After attending the University of Missouri, Allenbrand went with John Deere Plow Company in 1923 as an employe in its transfer house at Wichita, Kansas, and later at Sterling, Colorado. He later became travelling representative for the company, with headquarters in Kansas City, joining Caterpillar Tractor Company in April, 1931, as a special representative in the general sales department. Within six months, he was transferred to the sales training division, and in 1932 was made sales training representative for the western division with headquarters at San Leandro, California. After a short period with a Caterpillar distributorship in California, he rejoined the company as assistant manager of the sales training division.

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